ELEMENTARY

GEOLOGY

OF

TENNESSEE,

BEING ALSO

An Introduction to Geology in General.

By JAMES M. SAFFORD, A. M., PH. D. M. D.,

AND

J. B. KILLEBREW, A. M., PH. D.

NASHVILLE:
ALBERT B. TAVEL.

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AN INTRODUCTION TO GEOLOGY IN GENERAL.

DESIGNED

FOR THE SCHOOLS OF TENNESSEE.

BY

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PREFACE.

The accompanying work on the Geology of Tennessee has been prepared in response to a demand from teachers in every part of the State. Owing to the pressure of other duties its publication has been unintentionally delayed because the authors were unwilling to send forth a work erroneous in statement, or unsatisfactory in detail. The principal aim has been to supply a text-book on the general Geology of the State, the distinctive features of which should be: 1st, its scientific accuracy; and, 2d, its immediate practical utility at a time when the industrial development of our section of the continent is engaging the earnest attention of political economists, and that the students of our public and private institutions of learning may go forth armed and equipped with such knowledge as the demands of the age render imperative.

The work is written in as simple style and with the introduction of as few technical words as practicable. The illustrations are numerous and the maps, which will be of great assistance to the student, have been prepared with much care.

In the work will be found descriptions of th topographical features of the State, its formations, fossils, rocks, minerals and ores; and leading the student beyond the mere details of geography it will induct him into the wide domain of geological science.

The study of the crust of the earth, which is the object of Geology, is at the same time one of the most interesting and one of the most important that can engage the attention of rational creatures. The soils which produce our food, the coal which warms our homes, the ores from which the machinery and utensils of civilized life are made, the stones and clays from which our buildings are constructed, the gems and precious metals that are used for ornament, or as the basis of our currency—all these are matters properly treated of in a work on Geology. The habits of observation and investigation which the study of Geology engenders, and above all the great army of eager inquirers into the hidden resources of the State which would yearly go out, are sufficient reasons why Geology should take its place among the studies of our schools.

The authors hope that the work may prove acceptable to teachers, and that it may be the means of awakening an interest in a science which lies at the very foundation of all material progress.

Questions upon the text will be found at the end of the book.

July 13, 1876.

GEOLOGY OF TENNESSEE.

INTRODUCTION.

A GEOLOGICAL SURVEY OF THE STATE. THE USES AND PLAN OF THE SURVEY.

1. **The Survey, its Objects.** — We invite the young people of Tennessee, and all others who desire to commence such studies, to join us in a geological survey of the beautiful State in which we live. The object of the survey is to learn something about the highland and mountain-ranges, the great valleys and plains of the State, but more especially, to inform ourselves as to its rocks, minerals, ores, and soils. The first of these, the highland and mountain ranges, the valleys and plains, are external features which make up the surface or face of the country; the others lie chiefly below the surface and constitute the earth and rock-foundations beneath our feet. All combine to adorn and enrich the State, and not to know something about them can hardly be excused in any who claim or soon expect to be good citizens.

2. **Uses.** — The survey will be a pleasing work if entered upon with spirit, and the information acquired

will be useful in many ways. Such knowledge will enable us to think and talk about Tennessee as well informed persons only can; it will enable us to tell what it is that makes the State beautiful, healthful and attractive, and wherein consists its native wealth; it will put it in our power to aid in the development of this wealth, much of which lies useless, or hidden, in our hills and mountains; it will help us to appreciate the kinds, distribution and value of our soils; it will, in brief, make us more intelligent, better miners, better farmers, and, last, though not least, better men, for it will, like all true knowledge, refine our minds and lead our thoughts from nature up to God, the Creator.

3. **The Plan.**—In any undertaking it is well to have a plan before us in accordance with which to proceed or work. It is quite essential in this instance. Below, the course of the survey, or in other words, the plan of this book is given, and students will do well to pay especial attention to it. If the plan is understood, the relation of the different parts of the work will be seen, the chapters and larger divisions will explain each other, and the unity of the whole will be made apparent.

4. I. **The State in General.**—At the beginning of our inquiry, we ought to take a cursory view of the State regarded as a whole. We must know its boundaries, shape, and area. We must pass over its surface, noting the portions which rise in mountains and highlands, and those which sink in basins and valleys, or, in other words, we must see how its surface is naturally divided. Nor will it be amiss to inquire into the elevation of the State above the sea, its river-system, climate, and other features. These are general charac-

teristics, and a knowledge of them places the field fairly before us.

5. II. **The Surface-divisions.** — After this general view, we can study the special features of the surface-divisions, the extent and form, the height or depth, as the case may be, the river-system or drainage, whether presenting rich or poor lands, and whether populous or not. This will be, in the main, preliminary to what is to follow, but the information thus gained will be full of interest, and highly desirable in itself.

6. III. **The Rock-beds, or Strata.**—Our third step will be to investigate the rocks which, though sometimes *outcropping,* or showing themselves, in glades, ledges, and cliffs, lie mainly beneath the surface. To prepare ourselves for this, we must first become familiar with the different kinds of minerals or mineral substances which enter into the composition of rocks, and then with the various kinds of rocks themselves, all of which might be done *in a room,* with hand specimens of proper minerals or rocks on a table before us. This accomplished, we will be ready to study *in the open air* the rock-beds or strata which make up the hills and mountains, and underlie the valleys. We shall see that they lie in a horizontal position, or are inclined, that they are thick or thin, of limestone, sandstone, shale, slate, or other rock, that they sometimes contain the remains of animals, as shells and corals, often in great profusion, as well as the remains of plants.

7. IV. **The Geological Formations.**—The next stage

of our survey will be to make out the great formations of the State.

And first, what do we mean by *formation?* How does it differ from a rock-bed, or *stratum?* The word *stratum* is a Latin word, and means that which *is spread out;* the plural is *strata.* A stratum is a bed of the same kind of rock, as a stratum of limestone, or a stratum of sandstone. It includes all of any one kind that lie together. It may be a few or many feet thick, and may consist of many *layers*, provided they are all of the same rock-material. A *formation* is often a series, or a pile, of many strata. It may include beds of limestone, sandstone, and of other rocks. It is a *series*, the strata of which have been formed or deposited successively in what geologists call one *age*, or one *period*, of time. The Carboniferous formation is an example. This embraces many beds of sandstone, limestone, shale, and coal, alternating more or less with each other. The series makes a formation because the strata were deposited during the age when the coal beds were formed—an age of long duration—when the lands in many regions were covered with a forest growth remarkable for its luxuriance, and for the strange forms of its shrubs and trees.

The making out of the formations found in Tennessee, will be in some respects the most important part of our work. They constitute, as we shall see, the foundation of geological science. We have to determine as nearly as we can the thickness of each, the kind of strata making it up, the areas within which it outcrops, or comes to the surface, the fossil remains imbedded in it, the ores, minerals, useful rocks and soils it contains or may yield.

8. V. **Economic Geology—The Minerals, Ores, Useful Rocks and Soils.**—With the formations determined and disposed of, as mentioned in the last section, our survey will be well advanced. It remains to go over and

glean the field, bringing together in a body, for further notice and easy reference, all that may have economic or practical value. In this class we include coal, iron-ores and other ores and minerals, marble, cement-limestone, and useful rocks generally, and lastly, soils. In connection with these, important ore-banks and mines may be described.

PART I.

THE STATE IN GENERAL, OR CONSIDERED AS A WHOLE.

CHAPTER I.

The Form, Area, Boundaries, and River-system.

1. Before taking up the surface-divisions of the State, its different formations, minerals, ores, and soils, and considering them one by one, it is best, as already stated, to study the State as a whole, and learn its form, size, position among the other states, and the features generally which properly belong to it as one area. This, we repeat, will place the field to be surveyed fairly before us.

2. Form, Length and Width, Area and Boundaries, and River-system.—When seen upon the map, the State of Tennessee has nearly the form of a long rhomboid. (Fig. 1.) While its average width is only 109 miles, its length is as much as 385, which makes the State three and a half times as long as wide. A straight railroad track connecting its two sharp diagonal corners, the one near Memphis, and the other to the north-east on the Virginia line, would be nearly 500 miles long. The entire area of the State is about 42,000 square miles.

Fig. 1.

A Rhomboid.

3. On page 9 is a *surface*, or *topographical* map of

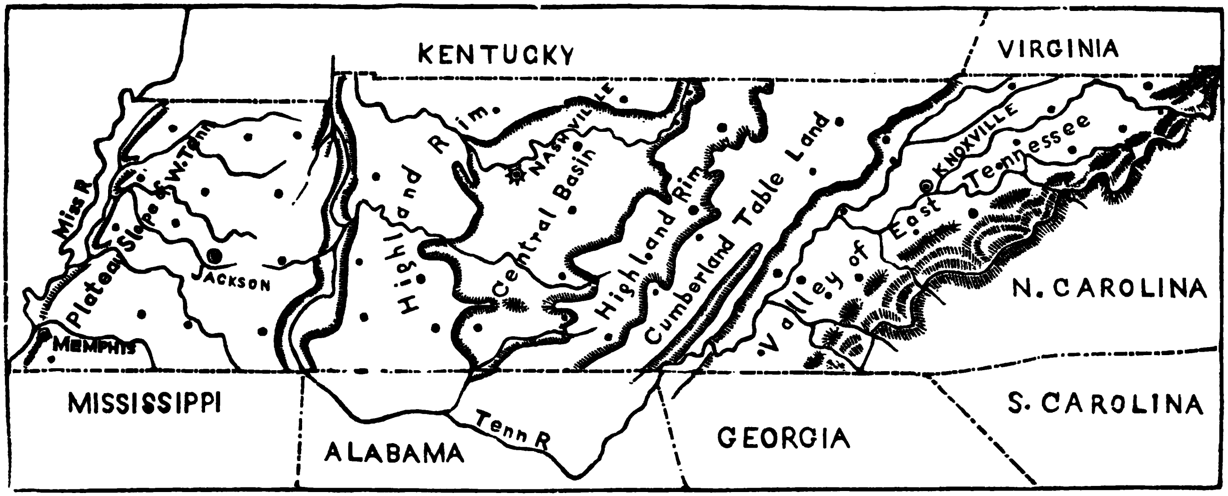
the State. It shows the form and boundaries of Tennessee, and gives the names of all the states which touch it excepting Missouri and Arkansas. Eight states touch our borders. With the exception of Missouri, no other state in the Union is touched by so many.

4. East and West Boundaries, the Westerly Inclination and Drainage.—Tennessee lies lengthwise, directly east and west, between the crest of one the highest ranges of the Appalachian Mountains and the Mississippi River. Its eastern boundary, or, as we may say, its North Carolina boundary, has an average elevation of 5,000 feet above the sea, while the lowlands bordering the Mississippi rise to the height of only about 300. This indicates a great tilting or inclination of the surface to the west. The inclination exists, but in a far less degree than the difference in the elevation of the two boundaries would denote. The eastern mountains form a very massive and raised border, but they do not reach very far into the State. At their foot lies the great *Valley of East Tennessee* (see map), the average elevation of which is not much above that of the middle portion of the State. This elevation may be placed at 1,000 feet above the sea. From this valley the general surface of the State, excluding the *Cumberland Table-land*, which, as we shall understand hereafter, is a great barrier in the way of the rivers, descends very gradually to the west. The average direction of drainage, or the average direction in which the waters flow, conforms to this. It may

be observed, and the map shows it well, that the rivers flow, to a remarkable degree, in two directions, one to the south-west, and the other the north-west. The tendency, or mean direction of the two, however, is westerly.

5. **River System.**—The State is rich in water courses. Hundreds of streams water the land, supply motive power, and enliven the valleys. The Mississippi, the Tennessee, and the Cumberland, with their principal tributaries, are the rivers of the State. The Tennessee and the Cumberland pour their contents first into the Ohio, and then into the Mississippi, so that all the water which drains off from the surface of Tennessee (with the exception of that from a small spot near a corner of the State, next to the Georgia line, and hardly worth the mention,) finds its way through the Mississippi to the Gulf. The three rivers named are navigable, and are means of transportation, much to the advantage of the State's material interests. The Tennessee river is peculiarly our own. Its principal head-waters are in Virginia and North Carolina. Starting in Virginia, its waters cross Tennessee twice, receiving many tributaries, and draining two-thirds of the State. The Cumberland has no great volume of water, but is remarkable for being navigable, canal-like, for 600 miles, 304 of which are in Tennessee, and the remainder in Kentucky.

It will be well for the student to trace out these rivers on the map, observing where they are, how they run, and what position they have with reference to the mountains and each other.



SURFACE-MAP OF TENNESSEE.

Scale, about 75 miles to the inch.

Note.—The following natural divisions are not named on the map: the Unaka Range of mountains bordering the North Carolina line, the Western Valley of the Tennessee river, the narrow valley through which the Tennessee river runs into Kentucky, and the Mississippi Bottoms a low and narrow area bordering the Mississippi river. The name *Plateau Slope of West Tenn.*, ought to run through Jackson to be in the centre of the division which it indicates.

CHAPTER II.

Special Features of the Eastern Portion of the State, and the Great Appalachian Belt.

6. Special Features of the Eastern Portion.—In its surface configuration Tennessee may be divided into two portions, an eastern and a western, the former containing mountains, and the latter without mountains. Referring to the map on page 9, the eastern portion embraces the mountains bordering the North Carolina line, the Valley of East Tennessee, and the Cumberland Table-land, while the western is the remainder of the State. Now, with the map before him, the student cannot fail to see that the mountains, valleys, and most of the larger streams of the eastern portion, run in a north-easterly and south-westerly course, and diagonally across the State. (See also map on page 116). This is a striking characteristic of the eastern portion. On a large map, giving the minor ridges, streams, and valleys, it would be brought out in still stronger light—all, or nearly all, would run in parallel courses to the north-east and south-west. Why is this? We are not ready for a full explanation now, but as a first step it is sufficient to say that this part of Tennessee is a section of a long strip of mountainous country, lying in the United States and Canada, called the *Appalachian Belt.* A short description of this belt becomes necessary.

7. The Appalachian Belt of Mountains and Valleys—Extent.—Upon examining any good map of the United States and Canada, embracing the country between the Gulf of Mexico and the Gulf of St. Lawrence, we shall see a long, comparatively narrow area, reaching in a south-westerly direction through Vermont to Middle Alabama, and traversing all the intermediate States, which is remarkable for its long, straight, and parallel mountains and valleys. This is the Appalachian belt. It is a very prominent feature on the map. The length of the belt is 1,200 miles; its width, from 50 to 100. The long area looks very much as if some monster giant had run a plough from Canada to Alabama, throwing up the earth and rocks in a band of mountain ridges, with deep and often wide furrows between.

8. Mountains and Valleys of the Belt.—Many of the mountains and valleys of the belt have special names, and are well known. The *Alleghany Range* of Pennsylvania and Virginia becoming the Cumberland in Tennessee, and the Sand mountain in Alabama, the *Blue Ridge* of Pennsylvania, Virginia, and North Carolina, the *Unaka* or *Smoky Range,* the *Holston,* the *Clinch,* and *Lookout* of Tennessee, are a few among the many mountains and ridges that might be named. The valleys, long and straight, lying between parallel ridges, and overlooked by them, but open to the north-east and south-west, are often rich, populous, and beautiful—paradises in which industry, intelligence, and worth find perfect contentment. Such are many val

leys in Eastern Pennsylvania, Middle Virginia, and East Tennessee.

9. **"Up and Down" and "Across" the Belt.**—Within the Appalachian Belt "up and down the country" is through the valleys to the north-east and south-west, and this is the general direction of water-flow and of travel. "Across the country" is at right angles to this, and he who travels across, faces ridge after ridge in quick succession, as a swimming bird does the waves.

10. **Great Valleys and Minor Valleys.**—The single valleys are often separated from each other by a mountain range, but, in some sections of the belt, they are separated only by low, or comparatively low ridges. In the latter case, when many of them, with their ridges, lie together between high and distant ranges, they constitute a *great valley*, the single valleys themselves being called *minor valleys*, and their separating ridges *minor ridges*. Viewed from the highest points, a country fluted with minor ridges and valleys appears to be almost a plain.

11. **The Valley of East Tennessee an Example.**—The great Valley of East Tennessee shown on the map (p. 9) is an example. This lies between the eastern border mountains and the Cumberland Table-land, and has an average width of 45 miles. Looked upon from the high summits of the North Carolina line, its area appears much like a low plain, but in traveling across it, the seeming plain becomes a succession of minor ridges and valleys, and, indeed, of no insignificant size.

12. Thus we see that the long area which is called the Appalachian Belt, is singular for the extraordinary parallelism of its valleys and ridges, and for the uniformity with which they run in a north-easterly and south-westerly direction. The fact that the

eastern part of the State is a section of this belt, throws light upon what we see there as to the direction and character of its mountains and valleys. The peculiar features are Appalachian, but for a thorough understanding of them, we must refer the student to what will be said of the geological structure of the great belt, and of East Tennessee.

CHAPTER III.

The Natural and Civil Divisions.

13 **The Natural Divisions.**—Could we sail, at a high elevation, over the State from the North Carolina line to the Mississippi river, we would see that its surface is divided into eight very distinct geographical or natural divisions. The map on page 9 is intended to show these divisions, and it is necessary for the student, with the map before him, to study them out and learn their names, their shapes, comparative sizes, and whether they are high or low areas. This will be preparatory to a more detailed study of them in the next Part. Beginning on the eastern border the natural divisions are as follows:

I. THE UNAKA RANGE—High mountains with inclosed valleys

Not named on the map; it is the mountainous belt next to the North Carolina line.

II. THE VALLEY OF EAST TENNESSEE—A fluted region; a succession of parallel minor valleys and ridges—one of the most beautiful, populous, and fertile portions of the State.

III. THE CUMBERLAND TABLE-LAND, The region of coal, a high plateau or table, capped with sandstone.

IV. THE HIGHLAND RIM, OR RIM-LANDS, OR TERRACE LANDS, that encircle a basin of rich lowlands in the centre of the State.

V. THE CENTRAL BASIN, encircled by these rim-lands, the centre of wealth and political influence, and rich in all the elements of a high civilization.

VI. THE WESTERN VALLEY OF THE TENNESSEE RIVER — Narrow, irregular, generally productive, often swampy, sparsely settled, and in a state of comparative wildness. Not named on the map, but indicated. One of the small divisions of the State.

VII. THE PLATEAU OR PLATEAU-SLOPE OF WEST TENNESSEE—Hilly on the eastern side, then flat or gently rolling to the Mississippi Bottoms; streams sluggish; forests heavy; soils fertile, capable of subsisting a great population.

VIII. THE MISSISSIPPI BOTTOMS—Much of the area dark, with a dense vegetation; spotted with lakes and marshes; thinly populated; soils of great fertility. Not named on the map. It is a narrow strip bordering the Mississippi river.

14. Of these divisions the Highland Rim is the largest, the Valley of East Tennessee being nearly of equal size. The Plateau-slope of West Tennessee comes next, then the Central Basin and the Cumberland Table-land, the two last having about the same area. Succeeding these we have the smaller divisions, which, in the order of size, are the Unaka Range, the Western Valley of the Tennessee River, and the Mississippi Bottoms.

The approximate areas of the different divisions, in their natural order, are as follows:

Unaka Range	2000	square	miles.
Valley of East Tennessee	9200	"	"
Cumberland Table-land	5100	"	"
Highland Rim	9300	"	"
Central Basin	5450	"	"
Western Valley of the Tennessee River	1200	"	"
Plateau-slope of West Tennessee	8850	"	"
Mississippi Bottoms	900	"	"

15. It will be seen that the natural divisions lie lengthwise across the State, and to a great extent diagonally across. As to the three most easterly divisions, the student's attention has been called to them on page 10. It has been shown that these divisions are included in the Appalachian Belt in which the mountains and valleys run in a north-easterly and south-westerly course. The others have a decided tendency to run in the same direction.

16. Civil or Political Divisions.—Three *civil* or *political* divisions have been constructed out of the eight natural divisions, as follows:

I. EAST TENNESSEE.—Comprising all the territory from the North Carolina boundary to about a line passing through the centre of the Cumberland Table-land, embracing the first and second natural divisions, and about half of the third.

II. MIDDLE TENNESSEE.—Extending from the dividing line on the Cumberland Table-land to the Tennessee river, and comprising the whole of the fourth and fifth natural divisions, and about half of the third and sixth.

III. WEST TENNESSEE.—Extending from the Tennessee river to the

Mississippi, and including the whole of the seventh and eighth natural divisions, and half of the sixth.

These three civil divisions are sub-divided into 94 counties. of which East Tennessee has 34, viz:

Anderson,	Greene,	Knox,	Rhea,
Bledsoe,	Hamblen,	Loudon,	Roane,
Blount,	Hamilton,	McMinn,	Scott,
Bradley,	Hancock,	Marion,	Sevier,
Campbell,	Hawkins,	Meigs,	Sequatchee,
Carter,	James,	Monroe,	Sullivan,
Claiborne,	Jefferson,	Morgan,	Unicoi,
Cocke,	Johnson,	Polk,	Union,
Grainger,			Washington.

Middle Tennessee has 40, viz:

Bedford,	Franklin,	Macon,	Rutherford,
Cannon,	Giles,	Marshall,	Stewart,
Clay,	Grundy,	Maury,	Sumner,
Cheatham,	Humphreys,	Montgomery,	Trousdale,
Coffee,	Hickman,	Moore,	Van Buren,
Cumberland,	Houston,	Overton,	Warren,
Davidson,	Jackson,	Putnam,	Wayne,
Dickson,	Lawrence,	Perry,	White,
DeKalb,	Lewis,	Smith,	Williamson,
Fentress,	Lincoln,	Robertson,	Wilson.

West Tennessee has 20, viz:

Benton,	Fayette,	Hardeman,	McNairy,
Decatur,	Gibson,	Henry,	Obion,
Dyer,	Henderson,	Lake,	Shelby,
Carroll,	Hardin,	Lauderdale,	Tipton,
Crockett,	Haywood,	Madison,	Weakley.

CHAPTER IV.

Climate.

17 Climate Defined — Its Effects.—By climate is meant the condition of a place in relation to its temperature, moisture, and winds, all more or less connected with the atmosphere. The character of climate is closely related to latitude, height, mountains and their direction, proximity of large surfaces of water, and by the nature and color of the soil.

Climate has a most important effect upon the industry of a country. If too hot, men are enervated and will not work; if too cold, they cannot work; if too moist, diseases are generated and the habits of industry destroyed; if too dry, the labors of the husbandman are not rewarded by a bounteous yield of the products of the earth. The best climate is that in which the amount of sunshine and rain, of cold and heat, is just sufficient to produce what man needs for his sustenance, comfort, and health, and where the body is kept in vigor by a proper degree of cold, without being debilitated by too much heat.

In treating of the climate of the State we shall consider, 1st, the temperature; 2d, the amount of rain-fall; and 3d, the prevailing winds.

18. Temperature. — The mean annual temperature, that is, the average degree of heat which prevails

along a line running east and west through the centre of the State, is, for the

Unaka Range	42°
Valley of East Tennessee	57°
Cumberland Table-land	54°
Highland Rim	57°
Central Basin	58°
Plateau of West Tennessee	59°
Mississippi Bottoms	60°

The figures may be modified slightly by future observations. It will be observed that the difference amounts to 18°. This is due mainly to elevation. The mean annual temperature of the Unaka Range corresponds with that of the southern parts of Canada, while that of the Mississippi Bottoms is identical with the temperature of Middle Georgia. In going from the southern boundary of the State to the northern, on the same level, there is a variation of about two degrees.

19. The Annual Temperature Compared with that of other Countries.—The mean annual temperature of Tennessee is that of some of the most delightful regions of the globe. Its isotherms (that is lines joining places having the same mean annual temperature) extend through North Carolina, Spain, the southern parts of France, Italy, Greece, Smyrna; cross the Caspian Sea near its southern extremity; passing on through the tea-growing districts of China and the Japan Islands, and re-enter the United States near San Francisco. It will thus be seen that the lines of equal heat do not correspond with the lines of latitude. Nor do they indicate an equality in climate, for though the mean annual temperature is the same, the variation in heat is not so great in the European states mentioned as in Tennessee. The summers of Tennessee are hotter, and the winters colder. For this reason the orange, the olive, and the

lemon do not mature in our climate. But for growing those plants that require a high degree of heat, such as Indian corn, tobacco, cotton, and melons, Tennessee far surpasses the countries of the same isotherms in Europe.

20. Summer Temperature, and Extremes of Temperature.—The average or mean summer heat of the several divisions of the State differ more widely than the winter means. The winter means are very much the same, being about 38°. The mean summer heat of the Unaka Range is about 62°, making these airy heights a delightful abode during the warm weather. For the Valley of East Tennessee it is 73°, which is about the same as the summer temperature of Philadelphia. The summer of the Table-land is about 70°, though on the edges overlooking the valleys east and west, it is two or three degrees cooler. Of the Highlands the mean summer heat is 74°; of the Central Basin, 76°. West Tennessee has summer means about one degree higher than the Central Basin. The temperature, as shown by observations for twenty-one years, has only once been as high as 99°. This was in July, 1860, and the observations were made in Montgomery county. The greatest degree of cold was observed at the same place in January, 1857 and 1864, and reached 8° below zero, making the greatest variation in heat for the period covered by these observations 107°. Our coolest weather occurs geneally in January; the warmest in July.

21. Winter Temperature—Ice.—The winters are usually cold enough in the northern half of the State

to secure ice. A median line, drawn east and west through the State, is the southern limit of domestic ice houses. South of this the ice season is too uncertain to justify the expense of constructing them. Ice sometimes, but very rarely, attains a thickness of ten inches on the northern borders of the State. Its usual maximum thickness is from two to three inches.

22. Frost.—One of the most important elements in climate is the period between killing frosts, because this measures the length of the growing season. Observations made by Prof. Wm. M. Stewart, of Montgomery county, extending through a period of twenty-three years, show the average number of days for each year free from frost to be 173, and from killing frosts 189. The longest period in any one year was 228 days; the shortest, 162 days. The first of these periods occurred in 1852; the last in 1872. These may be regarded as the limits of the longest and shortest periods in the northern portion of the State.

23. The most destructive frosts are in April and October. From the third week in April to the middle of October, the probabilities are against the occurrence of killing frosts. In the southern part of the State the period between killing frosts is twelve or fourteen days longer. This difference has an important effect upon the agriculture of the State, making cotton, except in the mountainous division, the staple in the southern counties, and tobacco and wheat the chief products in the northern counties.

24. Rain.—The average annual fall of rain upon

the surface of the globe is about 60 inches. In the Torrid Zone it is 96, in the Temperate Zone 36, and in the Frigid Zone 12 inches. The rainfall of Tennessee (including melted snow) is greater than the average for the Temperate Zone, being about 46 inches annually. This is just sufficient to insure a vigorous growth of vegetation, without interfering with the proper cultivation of the earth. It makes neither a wet nor an arid climate.

25. In the table below is given the rainfall in the northern part of the State for each of the years from 1852 to 1875 inclusive:

Years.	Inches.	Years.	Inches.	Years.	Inches.
1852	49	1860	40	1868	45
1853	37	1861	48	1869	39
1854	43	1862	50	1870	49
1855	44	1863	54	1871	48
1856	39	1864	41	1872	34
1857	43	1865	60	1873	53
1858	54	1866	45	1874	49
1859	49	1867	49	1875	55

26. The greatest quantity of rain usually falls in the month of April, then follow in succession December, March, February, May. The dryest month is October, the next September. The greatest annual rainfall shown in the table above, occurred in 1865, and amounted to 60 inches, the average annual rainfall of the globe; the least rainfall occurred in 1872, which was not quite 34 inches, corresponding with the average of the Temperate Zone.

27. **Snow.**—The average annual fall of snow within

the period embraced by the table, is seven inches. The heaviest snowfall was ten inches in depth. This depth of snow occurred twice, once in January, 1852, and again the same month in 1859. The year 1867 is noted for having the largest aggregate snowfall, which amounted to 27.75 inches. Some few snows have occurred in the State of a greater depth than ten inches, though they were at long intervals. One occurred in 1840 thirteen inches deep, but it did not extend over the State.

28. Winds.—Two systems of winds effect the climate of Tennessee, a *lower* and an *upper*. The lower consists of currents flowing to the north and north-east. These come charged with warmth and moisture from the Gulf of Mexico, and give to the State a genial and fruitful climate. The direction of the mountain ranges is such as to facilitate the passage of these life-giving breezes over the State.

The upper system embraces winds from the north and north-west, which flow above the first system, making with this a general circulation. The commingling of these two systems, brought about by changes of temperature and rains, gives rise to westerly and north-westerly winds. The easterly and south-easterly winds result from other influences apart from the general laws that govern the movements of the other winds, and may be called abnormal. The winds from the south, west, and south-west are the most frequent and the most desirable.

29. The fact has been established that the average

velocity of the wind in the region which embraces Tennessee, is less than in other portions of the United States. This takes Tennessee out of the path of frequent storms, giving it a delightful climate, highly favorable to the development of vegetable and animal life.

30. Variety of Natural Features. — In concluding this Part it may be stated that Tennessee is remarkable for the *great variety* it presents in natural features. We have seen this in the number and the varied character of the natural divisions of its surface, and in its diversity of climate. It will also be made apparent in its geological formations, rocks, minerals, and soils. Nearly all the important natural features of the states around it are represented within its borders—brought together as if by way of contrast. Thus it has, on the one hand, some of the greatest mountains of the Appalachians, with their bald summits and ancient rocks; and, on the other, the lowlands, cypress swamps, and alluvial beds of the Mississippi; it has, well represented, the singular valleys and ridges of Virginia, the tobacco lands, the "barrens," and the blue grass lands of Kentucky; the orange-colored sand hills, the cretaceous beds and cotton soils of Mississippi. And thus we might go on around and specify characteristics of Alabama, Georgia, and North Carolina, which have their counterparts within our borders. But enough has been said to call attention to the fact that *variety in natural features* is a marked peculiarity of Tennessee.

PART II.

THE EIGHT NATURAL OR SURFACE DIVISIONS OF THE STATE.

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31. The names and some of the characteristics of the natural divisions have been given on pages 13–16. In this Part they are separately and more fully described, so far as their surface features are concerned. Their formations, minerals, ores, and soils will be treated of hereafter.

As the three most easterly divisions belong to the Appalachian Belt (p. 11), and have its characteristics, they may be thrown together in one chapter, the remaining five making another chapter.

CHAPTER V.

The Eastern or Appalachian Divisions, Comprising the Unaka Range, The Valley of East Tennessee, and the Cumberland Table-land.

I.—The Unaka Range.

32. Its Position, Mass, Elevation, Width, and Area.—This is a chain of mountains extending along the entire length of the eastern border of the State, a distance of 200 miles. It is the greatest of all the Appalachian ranges, and one portion, lying about midway between Virginia and Georgia, presents the great-

est mountain mass to be found anywhere east of the Mississippi river. The average elevation of the Range is 5,000 feet, but many of its peaks reach a height of more than 6,000 feet above the sea. For days the peaks are concealed in the clouds.

As already stated, its high crest is the line separating Tennessee from North Carolina, the range being divided between the two States. The portion within Tennessee (and to this we confine our attention) occupies a strip which, in width, will average thirteen miles, but varies from two to twenty, and has an area, as given on page 15, of 2,000 square miles. The area thus occupied is indicated on the map (p. 9) by the fine lines representing mountains, and lies between North Carolina and the Valley of East Tennessee.

33. The Range — A Belt of Parallel Ridges. The Main Axis.—The Unaka Range is not a single ridge, but is, in Tennessee, a belt of parallel ridges which vary at different points, counted across the range, from two to four in number. The easterly one, on whose crest is the North Carolina line, is the main axis, the others are lower and subordinate. The main axis (by axis is meant the main ridge, to which the others are subordinate) has many names applied to it at different points along its course, *Iron Mountain*, *Roan*, *Big Bald*, *Great Smoky*, and *Frog*, being some of them.

34. The Chilhowee Subordinate Range.—The most westerly, or north-westerly, mountains of the range lie detached from the spurs of the main axis, and just within the Valley of East Tennessee. They are

isolated mountains, but are arranged lengthwise, as may be seen on the map, along a curving line. These mountains are the first approached from the Valley, and are for that reason quite conspicuous, though much lower than the towering, cloud-capped crests behind them. This line of subordinate mountains may be called the *Chilhowee Range*. Among its mountains are the *Holston*, *Buffalo*, *Meadow Creek*, *English's*, *Chilhowee*, and *Star's* mountains.

35. Included Valleys and Coves.—Interlocked with the great ridges and spurs of the Unaka Range, or entirely surrounded by them, are many beautiful valleys and coves. The cultivated part of one county, Johnson, in the north-eastern corner of the State, is a mountain-hemmed cove, with no way of getting in or out except by scaling mountains, or passing through certain narrow, dark, and rocky gaps made by the streams. Other interesting coves are *Wear's* in Sevier county, and *Tuckaleechee* and *Cade's* coves in Blount. But these included valleys and coves, many more of which might be mentioned, are properly parts or outliers of the great Valley next to be described.

36. Cut Transversely by Rivers.—Notwithstanding the massive character of the Unaka Range, it is cut into many portions by the rivers which flow out of North Carolina. This is a remarkable fact. The rivers take their rise on the western slope of the Blue Ridge (an Appalachian ridge lying to the east in North Carolina, and not so high or so massive as the Unaka), flow in a north-westerly direction, and inter-

sect the Unaka Range in deep, grand cuts, often with cliffs on both sides rising hundreds of feet in height, the waters dashing over the rocks in long and roaring rapids. A few years ago these cuts were impassable for travellers, but now several of them supply good roads, and through four of them railroad lines have been surveyed. There are seven rivers thus cutting the range—all tributaries of the Tennessee.

37. The "Balds."—Generally the Unaka ridges are clothed with forests. The high summits, however, are often destitute of trees, owing to the cold of this elevation. Such places are called the *Balds*. They are treeless domes, capping the great mountains, yet they are covered with grasses, ferns, and small shrubs, some of which belong to a far more northern climate than is found in the valleys below. In the summer season the balds are favorite resorts for pleasure-seekers, and those who would escape the heat of the valleys. The cool air and the grasses attract herdsmen with their cattle, and in July and August the more desirable of the summits are often alive with stock of all kinds.

38. Views.—The views from the balds are magnificent. To the east in North Carolina is a vast sea of mountain billows; to the west in Tennessee, far below us, at the foot of the Unakas, lies the Valley of East Tennessee, its surface spread out like a checkered carpet, its inequalities, excepting a few prominent ridges to the north, being almost lost—the surface sinking down to a plain, dotted over with cultivated

spots. In the extreme distance the *Cumberland Table-land* is seen rising up dimly beyond the great Valley and bounding the view.

The climate of the Unaka Range has been already noticed (pp. 18–19). Hereafter we shall see that the oldest rock-formations, and many of our minerals and ores, are found in this range.

II.—The Valley of East Tennessee, or the Great Valley.

39. Boundaries and Extent.—Descending from the mountains, we enter the *Valley of East Tennessee*, a most beautiful and desirable portion of the State, embracing nearly all the wealth and population of the civil division we call *East Tennessee.* Its position and outlines are well shown upon the map. It lies between the Unaka Range on the south-west and the Cumberland Table-land on the north-west, the average distance between these divisions being about 45 miles. Though thus bounded by mountain walls on both sides, it is open to the north-east into Virginia, and to the south-west into Georgia. The city of Knoxville is near its centre, and Chattanooga at its south-western corner. Its area, including its outlying valleys and coves, is about 9,200 square miles, which is more than one-fifth of the area of the State.

40. Elevation Above the Sea.—The average elevation of the Valley has been placed at 1,000 feet above the sea. Its elevation on the Virginia line will average about 1,400 feet, at Knoxville about 900,

and on the Georgia line 800. Thus it will be seen that the greatest fall occurs before reaching Knoxville. Below this point it is much less. In the northern part of the Valley the rivers run rapidly, have more shoals, and are less suited for navigation than they are below Knoxville. Though not so well suited for navigation, a compensation is found in their fitness for water power.

41. A Succession of Minor Valleys and Ridges.—The Valley of East Tennessee has been so often referred to that the attentive student must be already familiar with its leading characteristics. Seen from the mountains, as we have stated (p. 12), its surface is almost a plain, but in crossing it we find it to be a succession of minor valleys and ridges, which run to the north-east and south-west, and, like furrows, in parallel lines. In this it conforms to the characteristic features of the Appalachian Belt, of which it is a part. It is well called a *fluted* area.

42. The Ridges of the Valley.—The ridges are very numerous, and differ in size, height, breadth, sharpness of outline, and in character of vegetation; while, at the same time, each one is remarkable for its direct course and uniformity in size and appearance from one end to the other, a distance often of a hundred miles or more. The ridges differ from each other, as will be seen, on account of differences in their geological character. They may be grouped into the following three classes:

43. (1.) MOUNTAIN RIDGES. — There are but few of these.

One, *White Oak Mountain*, a prominent ridge, starts up in the southern end of the Valley, is intersected by the railroad at a point nearly half way between Chattanooga and Cleveland, and extends into Georgia, where it is called *Taylor's Ridge*. All the others are in the northern part of the Valley, and most of them are prominent Virginia ridges, which, after crossing the line and penetrating the State for different distances, come very abruptly to an end.

Of these, *Clinch Mountain*, lying about half way between the Unakas and the Cumberland Table-land, is the most important. It is a bold, straight, sharp-crested sandstone ridge, sometimes rising a thousand feet above the Valley. It traverses the state for nearly 60 miles, its bluff end being almost in sight of Knoxville.

44. Between Clinch Mountain and the Table-land are *Newman's Ridge and Powell's Mountain*, a pair of Virginia ridges not extending so far into Tennessee. They lie closely together, the deep and cold valley between them being very narrow. To the east of Clinch and between Rogersville and Jonesboro is a bed of crowded and parallel sandstone ridges, called *Bay's Mountain*. This bed lies wholly within Tennessee.

45. (2.) BROAD RIDGES WITH ROUNDED OR NEARLY LEVEL TOPS.—These are numerous, and often of great length. Cultivated fields are found upon them, but their surfaces are generally covered with flinty gravel. The rock in them below the surface is limestone and *dolomite*. (Dolomite is a kind of limestone, containing, in addition to the lime, a similar earth called *magnesia*. It is sometimes known as *magnesian limestone*.) Knoxville is built upon one of these ridges, and the depot at Athens, in McMinn county, is upon the same ridge. Other examples are *Black Oak*, *Copper*, and *Chestnut ridges*. These are large ridges, crossed in going to the north-east from Knoxville to the coal mines in the Cumberland Table-land.

46. (3.) NARROW AND SHARP-CRESTED RIDGES, AND LINES OF KNOBS.—Often alternating with the broad dolomite ridges we have others that are steep and have sharp tops. When their crests are unbroken, they resemble a roof with two slopes. Usually their crest is more or less notched, and sometimes the ridge is so deeply notched that it becomes a *line of knobs*. Such a line, in which the knobs are prominent *red hills* starts up near Strawberry Plains, passes within sight of Knoxville on

the opposite side of the Holston river, runs near Athens, and almost reaches the Georgia line, altogether traversing the Valley for 100 miles. It looks not a little like a long line of potato hills of mammoth dimensions.

47. The Minor Valleys and Coves.—These have been referred to a number of times already (pages 11, 12). They are very numerous, like the ridges. All of them have names, which it is not necessary to enumerate. The valleys have great length, two of them, though not averaging more than a mile in width, run continuously through the State, from Virginia to Georgia, a distance of more than 150 miles. In general they vary in width from a few hundred yards to several miles. Most of them are fertile and beautiful. Some of the narrow ones are not inviting, being cold and unproductive.

48. Nearly every portion of a valley has its creek, flowing either to the north-east or south-west, in conformity with the direction of the ridges. If the creek escapes from one valley into another, it does so through a narrow gap in a ridge, and then only to flow off in a direction parallel to its first course.

49. The rocks of all valleys and coves that have agricultural importance are limestones, or soft shales intermixed with limestones.

50. Sequatchee Valley.—The valleys and coves interlocked with the Unaka ridges, or surrounded by them, are referred to on page 26. On the Western side, embraced in an arm of the Cumberland Table-land, is another outlier which deserves mention. This is *Sequatchee Valley*, a great, deep trough, cut lengthwise out of the Table-land, and dividing it into two parallel but unequal arms, the more easterly being *Walden's*

Ridge. **This valley has its head about midway between the northern and southern boundaries of the State, and extends to the Alabama line, a distance of 60 miles. It is from three to five miles wide, and is overlooked on both sides by the high edges of the Table-land.**

III.—The Cumberland Table-land.

51. Defined; Elevation, Area, Outlines, Walden's Ridge. Next in order comes the Cumberland Table-land, the third natural division of the State. This, as said on page 14, is the region of coal, a high plateau or table, capped with sandstone. It rises 1,000 feet above the Valley of East Tennessee, and 2,000 feet above the sea. It embraces 5,100 square miles, which is one-eighth of the State. The form, relative size, and oblique direction of the Table-land are seen upon the map on page 9. Its eastern edge is a nearly direct or gracefully curving line, while its western edge is notched and scalloped by deep coves and valleys, which are separated by finger-like spurs pointing to the west. At almost all points, on both sides, the surface suddenly breaks off in sandstone cliffs from 20 to 200 feet in height, giving everywhere a sharp and very prominent margin or brow to the division.

The splitting of the southern portion by Sequatchee Valley (see p. 31) is a noticeable feature. The easterly portion thus cut off, *Walden's Ridge,* is but an arm, as it unites with the main body of the Table-land around the head of the valley.

52. Surface and Soil.—The surface of the Table-land is often flat for miles. Then again it is rolling and

diversified, with hills and shallow valleys. In the north-eastern part of the division there are high ridges, containing many beds of coal, which may be regarded as mountains on the Table-land.

The soil of the division is sandy, thin, and porous, and of little agricultural importance.

53. An Obstacle to Free Intercourse.—This great Table, rising so boldly above the general level of the State, has always been a serious obstacle in the way of free intercourse between the eastern and middle portions of the State. Even now no railroad crosses it in Tennessee. To pass from Knoxville to Nashville, it is necessary to make a great circuit to the south through Alabama.

The Tennessee river, the natural course of which is north-westerly, is deflected by the Table-land to the south-west, and it is only in Alabama that the river succeeds in passing the barrier. The relations of the river to the Table-land may be seen upon the map.

For remarks on the climate of the division see Chap. IV. Its coal beds and coal will be described in the proper place.

CHAPTER VI.

The Non-mountainous Natural Divisions, Embracing the Highland Rim, the Central Basin, the Western Valley, the Plateau-slope of West Tennessee, and the Mississippi Bottoms.

54. The last chapter included the three Appalachian divisions, or those embraced in the mountain belt. In this we notice the five divisions lying west of this belt, in no one of which are there points rising much higher than 1,000 feet above sea-level. The latter are much simpler in

their surface features, and will not require such long descriptions. In these the valleys and ridges run in no determinate direction, and nothing is seen of the parallelism so prominent in the Appalachian divisions.

IV.—The High-land Rim, or Rim-lands, or Terrace-lands.

55. Extent and Rim-character.—Extending from the western base of the Cumberland Table-land to the Tennessee river, a distance of 120 miles, and encircling, as a flat country does a lake, the great *Basin* next to be described, is the *Highland Rim*, the fourth and largest natural division of the State. This is a great upland plain, 1000 feet above the sea, the central part of which has been eroded and washed out to form the basin mentioned. It is a *rim* around a *basin.*

56. The outside limits of the division, or of the Rim, and its relations to the other divisions, can be readily made out on the map (p. 9). In form it approaches a square. The portion west of the Basin is twice as wide as that on the eastern side. The entire area is 9,300 square miles.

57. Surface, Soils, Iron-ore Banks.—The surface of the Rim is generally flat. Many parts, however, are furrowed by streams, giving a pleasing variety of hill and dale. Large sections have rich and productive soils. These are thickly settled and in good cultivation. In other sections the lands are very poor, and have but few or no inhabitants.

On the western side of this division are iron-ore banks, remarkable for the quantity and purity of their

ores. These will be noticed under the head of *Economic Geology*.

V.—The Central Basin.

58. Name, Importance, Form, Rivers, and Area.— The area inclosed by the Rim is very properly named the *Basin*, and, from its central position, the *Central Basin*. It is the fifth division of the State, and the most important, so far as fertility of soil, density of population, and political influence are concerned.

The student will again consult the map on page 9. The Basin is seen to be oval in general form, to lie lengthwise across, but within the State, and to be the central area. Nashville, the capital, is within it. It has three rivers, the *Cumberland*, the *Duck*, and the *Elk*, and these escape from the Basin in narrow and deep valleys, or outlets, cut through the western and southern portions of the Rim.

The greatest length of the Basin is 120 miles, its greatest width 55, and its area 5,450 square miles—more than an eighth of the State. Its depth below the Rim will average 350 feet.

59. The Bed of a Drained Lake.—For the better understanding of this singular and important division, we may suppose it to be *the bed of a drained lake*, the edge or rim, which runs all around, having been the former shore. Indeed, if now the narrow outlets of the three rivers mentioned were dammed up level with the Rim, the entire Basin would fill with water and become a lake. At Nashville the lake

would be 400 feet deep, and one might sail over the city and never recognize its site. The summits of the highest hills of the Basin would stand out above the water as low, scattered islands.

The climate of the Basin has been considered in chapter IV., to which the student is referred. Its geological formations will be studied hereafter.

VI.—The Western Valley of the Tennessee River, or the Western Valley.

60. Character, Area, Elevation.—This follows next in order. It is comparatively a narrow valley, extending almost directly north and south through the State. (See the map.) The Tennessee river runs in a northerly direction through it, but the division is broken, and by no means such a valley as we should expect to find upon so noble a river. The soil is fertile, and many good farming regions are met with, but marshy areas, covered with cypress swamps, often occur. The average width of the valley is 10 or 11 miles. It has an area of 1,200 square miles, and an elevation of 350 feet above the sea.

This division has much geological interest, as future chapters will show. Its iron-ores, marbles, cement-limestones, and the "bald places" in McNairy and contiguous counties, will supply subjects of interest.

VII.—The Plateau, or Plateau-slope of West Tennessee.

61. Importance; Contrasted with the other Divisions. This division includes all the uplands in West Ten-

nessee. It is the seventh in order, and one of the most populous and important. It ranks third in size and second in population.

It is an area, not of limestones, sandstones, and other *hard* rocks, like the divisions we have described, but of clays, loams, and sands. For this reason it is like a new land to a traveler from Middle Tennessee. He misses the rocks in the bluffs of the streams, in the railroad cuts, and on the hills and ridges. The mellow soils are different, the rivers are sluggish, not like the rippling streams to which he has been accustomed. These are bordered by low, wide, and often marshy bottoms.

62. Plateau Character: the Bluffs, Rivers, Area.— This division is a plateau, sloping gently to the west. Its four-sided and nearly diamond form, with Jackson near the centre and Memphis in the south-west corner, can be seen upon the map so often referred to, and with which the student cannot be too familiar. The eastern border of the division, which is but little west of the Tennessee river, is, at some points, 600 feet or more above the sea. This border nearly coincides with the dividing ridge between the waters of the Tennessee and the Mississippi, and is known as the *Tennessee Ridge*. Thence the Plateau extends to the west for 85 miles, when it very abruptly terminates, falling off in a line of steep declivities called *the bluffs*, which overlook the great alluvial low plain, or *bottoms*, of the Mississippi. The fall of the surface from the eastern border to the bluff edge is 200

feet, and the average height of the bluff, above the bottoms, 130.

63. The map shows the division to be well veined with rivers. The most of these rise on the eastern border, and flow entirely across the Plateau-slope to the Mississippi.

The entire area of the division is 8,850 square miles, making more than a fifth of the State.

Notwithstanding the absence of *hard* rocks, it will be seen, in another Part, that the geological formations of this division are by no means devoid of interest. For climatic relations the student will refer back to Chapter IV.

VIII.—The Mississippi Bottoms.

64. A Low Plain, General Character, Soils, Area, Elevation.—We have now reached, in our westerly course, the last division of the State. Entering it we leave behind all the upland of Tennessee, and find ourselves on a low alluvial plain, which, at many points, is below the high-water mark of the Mississippi river. The division embraces all the bottom lands of the great river within Tennessee. It differs greatly from any other large section of the State. Much of the area is covered with swamps and lakes; much, too, is wild and dark, with heavy forests, even now the retreat of deer and other wild animals. Other portions, confined mostly to a belt bordering the river, are in a good state of cultivation. The soils are deep and of great fertility. When its lands shall have been reclaimed, settled, and put in proper culti-

vation, it will be the most productive part of the State.

65. The Mississippi river, by its windings, cuts the division into several unequal parts. Altogether, its area is 900 square miles, making it the smallest of the eight natural divisions. Its average elevation is not far from 270 feet above the level of the Gulf.

PART III.

THE ROCKS AND THE STRATA.

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66. On the last page we completed the survey of the *surface* of the State. The information thus acquired is of high value in itself; it will be indispensable in the work of describing and locating the formations, iron-ore regions, coal beds, marble belts, mines, etc.

In this Part, in accordance with the plan developed in the Introduction, the pupil will study the rocks and *strata*, the latter being but another name for the wide-spreading *layers* in which rocks occur; in the next, or Part IV., he will study the great formations, or the different groups of strata made out by geologists (see page 4); and in Part V., coal, ores, and other minerals, useful rocks, and soils, all of which are products, or parts, of the formations.

And here, before we go further, it will be proper to answer the question,

67. *What is Geology?* To study what we have just enumerated, as the subjects of this and the remaining Parts, is to study *Geology*. The word itself is from two Greek words, and signifies *the story of the earth.* As used here it means, in the words of Mr. Dana, "an account of the rocks which lie beneath the surface, and stand out in its ledges and mountains, and of the loose sands and soils which cover

them; and also an account of what the rocks are able to tell about the world's early history."

68. Geology explains how the rocks were made, why occurring in layers or strata, and how these, by the action of mighty forces, were raised out of the sea, elevated in mass, or folded in plaits, as if thick cloth, or broken and made to overlap, one edge upon another; and how since they have been worn or *eroded* by water, frost, and ice, and shaped into mountains and valleys. It points out the fact also that the strata contain the remains of extinct races of animals and plants, shells, teeth, bones, leaves, stems, and fruits, all of which has a most significant meaning. Every stratum thus filled is like a leaf in a book: it is a leaf in the earth's great rock-book, a part of a veritable history, and tells about beings of strange forms that lived when the materials, mud, etc., out of which the stratum was formed, were accumulating at the bottom of the sea. There are many leaves in this book, and thus does geology become the record of a wonderful story.

69. Again, Geology informs us about the ores and minerals, the particular rocks and the soils that man uses in so many ways in the industrial and domestic arts, and for the purposes of life, or from which he derives his means of subsistence. This part of the science is called *Economic Geology*.

CHAPTER VII.

The Minerals which Compose the Rocks. Silicates and the Scale of Hardness.

70. Minerals Making Tennessee Rocks.—Rocks consist of minerals. Granite, for example, is a mixture of three minerals, *quartz, feldspar*, and *mica*. Limestone is composed essentially of but one, *calcite*. The number of minerals entering into the composition of Tennessee rocks is not great; it is, indeed, very small, if we exclude the rocks of the Unaka Range. All that the student need consider are the ten following: *Quartz, calcite*, and *dolomite; feldspar, mica, amphibole, pyroxene, garnet, talc*, and *chlorite*. All but the first three are confined to the rocks of the range just mentioned.

71. The Ores.—The ores are minerals that can be profitably worked for the metals they contain, as the iron, lead, and copper ores, few of them are essential constituents of the rocks. They are properly considered in Part V.

I.—Quartz; Silicates, and the Scale of Hardness.

72. Characteristics of Quartz.—Common flint and the grains of pure, white, gritty sand are varieties of quartz. It is the material of grindstones, and of the best oil or whetstones. Of all the ingredients of rocks, quartz is the most common. The following are some of its characteristics, and by means of these it

may be distinguished from other common minerals: It is (1) one of the hardest of minerals, scratches glass easily, and strikes fire with steel; (2) it does not melt in the hottest fire; (3) it is not dissolved by water, nor by any common acid; and (4) it breaks as easily in one direction as another, resembling glass in this respect. It is a little more than two and a half times heavier than water.

73. Crystallized Quartz.—There are very many kinds of quartz, and its varieties present all colors. It is often found in colorless crystals, which are frequently as clear as glass. The accompanying figures indicate the outlines of two of its crystalline forms. Similar crystals, with others of more complex forms, are found at many localities in Tennessee, especially in some of the counties of East Tennessee. Very often the crystals are attached by one end to a surface of rock, making the surface brilliant with little pyramids of quartz. At a number of points on the Highland rim, hollow balls of rock, called *geodes,* are found, which are rough on the outside, but when broken, display an inner surface thickly studded with the brilliant, glassy-looking pyramids of this mineral, which sparkle in sunlight almost as if they were diamonds.

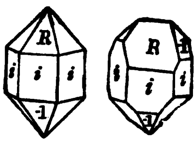


Fig. 2. Fig. 3.

74. The region of the Hot Springs in Arkansas is a noted place for large and clear crystals of quartz, or *rock crystals,* and specimens are often seen in cabinets, and as curiosities on mantels. Such crystals are

sometimes cut and polished as lenses to take the place of glass in spectacles. They are also cut to make gems in imitation of diamonds. When the crystals are of purple color, a stone cut from them is called an *amethyst,* and when yellow, *false topaz.* *Rose quartz* is simply a massive variety, colored rose-red or pink. *Smoky* and *Milky* quartz are other varieties, the first having a smoky-yellow or smoky-brown color, and the other being milk-white and opaque.

75. Concretionary Quartz or Chalcedony.—Under this head are included varieties of quartz that are not crystallized or glassy. They are more like wax or rosin in structure, and often in appearance, some of them having a waxy lustre and look, though of course very hard.

The word *concretionary* refers to the fact that the particles of specimens of this kind are united, as is the case in glue or wax, without showing ordinarily any crystalline form, structure, or grains, such as we see in alum, rock-candy, salt, coarse sugar, and in many other common substances and minerals. Sometimes specimens of concretionary quartz have their particles arranged in layers, and often of different colors, just as we might arrange layers of wax by piling one upon another. The layers may be either flat or wavy, or they may be arranged around a centre (*concentric*) like the coatings of an onion, in which case the specimens are called *concretions.*

The concretionary varieties of quartz are not so common or important as the crystallized. They do not enter largely into the composition of rocks. Some of them are interesting only as supplying ornamental stones, or as elegant material for the manufacture of small mortars for chemists and mineralogists, knife-handels, seals, and such articles. When polished, they present beautiful surfaces.

76. *Chalcedony* proper has the lustre nearly of wax. Some specimens are transparent, others permit the light to pass only, and imperfectly, through the edges, or in other words, are *translucent.* Its color may be white, gray, brown, blue or black. When of other colors it has other

names. *Cornelian*, so often seen in ear-rings, finger-rings, breast-pins, and other jewelry, is a clear red or brownish red chalcedony, the brownish kinds being also called *Sard*. *Chrysoprase* is an apple-green chalcedony. *Agate* is a name applied to variegated chalcedony, presenting often several different colors. The colors may be arranged in layers, or in clouds, or may be due to visible impurities. It is *Banded* or *Ribbon agate* when the different colors are in layers, whether these be wavy or concentric. If the layers are zigzag the name *Fortification agate* is sometimes used. The clouded kinds have no very well defined names. *Moss-agate* is a variety having brown, moss-like forms distributed through the mass. *Onyx* is an agate with the layers not only of different colors, but parallel and even. It is used for *cameos*, the head being cut in one color, and another making the background. In ordinary onyx the layers are alternately black and white. In the *Sardonyx* the layers are brownish-red, or sard, and white.

77. *Flint* is somewhat allied to chalcedony, but more opaque, and of dull colors. It breaks with a sharp, cutting edge, as seen in gun-flints. *Hornstone* is like flint, but more brittle. *Chert* is an impure flint, or hornstone. *Buhr-stone*, out of which mill-stones are made, is a spongy or cellular, flinty rock, which may be considered a variety of coarse chalcedony.

78. **Jaspery Quartz.**—This is an impure colored quartz, neither crystalline nor having a waxy lustre. One kind, much admired, is *Heliotrope*, or *Bloodstone*, a sort of green chalcedony, with spots of red jasper, which look like drops of blood. The rough surface of jasper is dull, but it admits of a brilliant polish, and is often formed into vases, boxes, knife-handles, etc. Like chalcedony, it is also cut into stones for jewelry. Very fair specimens of chalcedony and jasper have been met with, and may be obtained in the coves and included valleys of the Unaka Range.

79. **Opal.**—This differs from quartz in containing water in its composition. It is not as hard or as heavy as quartz. It is of various pale colors, and sometimes, as in *Precious opal*, shows internally a rich play of colors.

In connection with the subject of quartz it will be best to explain the terms,

80. **Silica and Silicates.** — *Silica* is the *chemist's* name for quartz. The two names mean essentially the same thing. Silica comes from the Latin word *silex*, which means *flint*. Silica or quartz, when ana-

lyzed, is found to be a compound of two elements, *Silicon* and *Oxygen*, the first a non-metallic substance, only known to chemists; the other the most abundant of all elements—a gas, and a very important constituent of the air, without which we could not live, nor could coal or wood burn.

81. Silica has the power, especially in the state of powder or fine sand, of uniting with alkaline substances, such as potash, soda, lime, magnesia, and with the oxide of iron, oxide of lead, and similar substances, to form *glass*. For example, if a mixture of silica, potash, and lime, in the proper proportions, is heated in a very hot furnace, it will melt into liquid glass, all the different ingredients thoroughly uniting together to form a definite compound. Common glass is made in this way. Such a compound is called, in the language of chemistry, a *silicate*. If potash and lime are used with the sand, the glass will be a *silicate of potash and lime;* if soda and lime, a *silicate of soda and lime*, and so for the other alkaline substances. Thus, by varying the ingredients, different kinds of glass are manufactured, each one being a different silicate.

82. Now, many minerals are found in nature which have a composition similar to that of glass; in other words, they are *silicates*. They are generally crystallized, often in large and beautiful forms. They may be called crystallized native glasses. Such are *feldspar*, *mica*, *hornblende*, and other minerals we are soon to notice.

83. Quartz Rock.—Great cliffs, and even mountains, are made of quartz rock. It occurs in strata, and frequently in veins, cutting through the other rocks. Such strata and veins, the latter sometimes containing particles of gold, are met with in the rocks of the Unaka Range.

84. Sand and Sandstones.—The beds of sand in the rivers and elsewhere are made up in great part of quartz grains, for the reason that grains of most other minerals, being soft, wear out and disappear in the washing and moving of the sands by the currents of water. *Sandstone rocks* are also composed of quartz

grains; they are sometimes but little more than hardened beds of sand, the grains becoming cemented together or simply cohering. Quartz rocks differ from sandstones in not showing grains, or at least not so distinctly. They are more compact and glassy in appearance.

85. We have had occasion to speak of the *hardness* of quartz. Hardness is a relative term, and in order that the student may understand the degrees of hardness, and have the means of determining it, we here append,

The Scale of Hardness.—Mineralogists determine the hardness of minerals by comparing them with a set of selected minerals, the hardness of which is known. Quartz or flint, for example, is a mineral of known hardness. It scratches glass easily, strikes fire with steel, and is, therefore, harder than glass or steel. Minerals are often compared with quartz in order to ascertain whether they are harder or softer. The gems, such as the diamond, rubies, and emeralds, are harder and will scratch the quartz, but very many minerals are softer. Ten minerals have been selected by mineralogists as a standard of hardness, with which all minerals are compared. These make the *scale of hardness.* It begins with one of the softest minerals, *talc*, and ends with the very hardest, the *diamond.* Quartz, it will be observed, occupies the *seventh* place in the scale, and comes next before the precious stones.

86. The scale is as follows, talc being the lowest, and counted 1, the others following successively, showing the relative hardness by the figures prefixed:

1. *Talc.* Laminated green variety; easily scratched by the finger nail.
2. *Gypsum.* Crystallized variety; not easily scratched by the nail. Does not scratch a copper coin.
3. *Calcite.* Transparent variety. Scratches and is scratched by a copper coin.
4. *Fluor.* Crystalline variety. Not scratched by a copper coin. Does not scratch glass.

5. *Apatite.* Transparent variety. Scratches glass with difficulty. Easily scratched by the knife.
6. *Orthoclase.* White cleavable variety. Scratches glass easily. Not easily scratched by the knife.
7. *Quartz.* Transparent variety. Not scratched by the knife. Yields with difficulty to the file.
8. *Topaz.* Transparent variety. Harder than flint.
9. *Sapphire.* Cleavable variety. Harder than flint.
10. *Diamond.* Harder than any known mineral.

We notice here some of the minerals of the scale not described elsewhere.

87. *Apatite*, the fifth member of the scale, has the same composition as the ashes obtained by burning the bones of animals. It may be considered crystallized bone-ash. It is often found in nature in beautiful large crystals, and when of a yellowish green color is called *asparagus stone.* Near Charleston, in South Carolina, is a bed of a compact variety of apatite which resembles impure limestone. This is quarried out, and the pieces are ground and used extensively to fertilize or manure land.

Topaz, *sapphire*, and the *diamond*, when in solid, clear crystals, are precious stones, and of extensive use in jewelry. Topaz is a *silicate of alumina.* Its characteristic color as a gem is yellow.

88. Sapphire and Alumina.—Sapphire is *crystallized alumina*, and alumina belongs to the same class of substances that lime does, that is to say, it is alkaline or basic, though very feebly so. Like lime, it unites with silica or quartz to form native glasses or silicates; and topaz, just mentioned, is one of them. Alumina is the characteristic constituent of common clay, the clays being also compounds of alumina and silica, with which, however, there is combined more or less water.

The name *sapphire* is properly applied to the *blue* crystals of alumina; the *red* crystals are called *rubies;* the green, *oriental emeralds;* the *violet*, *oriental amethysts;* and the *yellow*, *oriental topazes.* These stones are next to the diamond in hardness, and have very great value.

89. A more common name for crystallized alumina is *corundum.* This name includes all the varieties, whether in handsome crystals or not. Sapphire, and other forms of corundum, are found in North Carolina, not very far east of the Tennessee line.

The common sorts of corundum, when reduced to coarse and fine powders, are sold as *emery*. These, on account of the hardness of the mineral, have great scouring and polishing properties.

90. Diamond.—The diamond is crystallized *carbon*. There are three very different forms of carbon; one is seen in common *charcoal*, another in the misnamed "*black lead*" of cedar pencils, and the third, in the *diamond*. The "black lead" of pencils contains no lead. The proper name for it is *graphite*, from a Greek word, which means *I write*. It is a soft, black mineral, very suitable for writing on paper—a use of it known to every school-boy. It is also used for polishing stoves, as a lubricating material in the place of grease for the axles of wagons, and for other purposes.

It is truly wonderful that a single substance like carbon can thus form three things so very different. Graphite is as soft as talc, which is only 1 in the scale of hardness, while the diamond is 10, or the very hardest of the scale. Charcoal is quite different from either; it burns easily, while graphite and the diamond burn with great difficulty.

The other minerals of the scale will be noticed, either in this chapter, as constituents of the rocks, or in Part V.

II.—Calcite.

91. What it is, and How occurring.—Calcite is, in rock-form, nothing more than *limestone*. The grains of limestone rock, of marble, and of chalk, are properly calcite. It does not occur, however, only in rock-form. We often find it in beautiful crystals in the cavities of the rocks and in veins, either alone or in company with other minerals and ores; it forms the curious "stony icicles" called *stalactites* which hang from the roofs of caves. It is deposited in compact layers, or as a mealy material (*marl*), from the waters of many strong limestone springs, and it is the white substance which collects on the inside of tea-kettles

in which limestone water is boiled. Calcite is also the principal part of oyster, snail, and other shells, as well as of many corals.

All rocks and substances made up of calcite are said to be *calcareous*. Limestone and chalk are calcareous rocks. Calcite itself is a calcareous mineral; it was formerly called *calcareous spar*, or *calc spar*. *Calx* is the Latin word both for limestone and lime.

92. Crystalline Forms.—Calcite crystallizes in many forms, some of which are represented in figures 4 and 5. Though these forms, or crystals, are so dis-

Fig. 4.

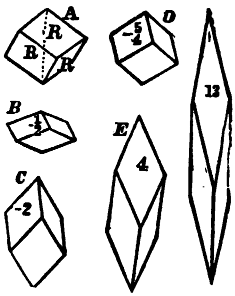
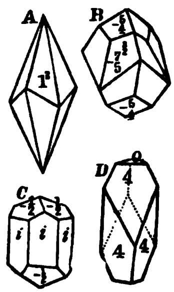


Fig. 5.



similar in appearance, yet all of them break alike and easily in three different directions, always breaking, or better, splitting, out a form or block similar to A in Fig. 4. This block has six similar sides, and is called a *rhombohedron* (rhom-bo-hé-dron). In Fig. 4 are six different rhombohedrons, and crystals of calcite occur in the shape of every one of them. If broken, however, the pieces have the form of the rhombohedron, indicated by A. A specimen of cal-

cite in which the crystals are flat rhombohedrons like B, is called *nail-head spar,* as they look something like the heads of wrought-iron nails.

In Fig. 5 we have other forms in which calcite crystallizes. That indicated by A is a very common form, and specimens showing the points of this form are called *dog-tooth spar.*

93. Clear, transparent crystalline pieces of calcite, are called *Iceland spar.* It gets the name Iceland because fine specimens have been found in that island. This spar has the curious property of making every thing appear double when seen through it. In place of one letter, line, or dot, we always see two. The crystals are much used in studying the subject of light.

94. Chemical Character.—Calcite is, in chemical language, *carbonate of lime* (calcic carbonate), that is to say, it is a compound of *carbonic acid,* which is a gas in the free state, and *lime.* If calcite, either in crystals, or in its rock-form, limestone, is heated red hot, as limestone is heated in a lime-kiln, it is decomposed, the *carbonic acid gas* being driven off in the air, and the *lime* remaining. Carbonic acid may also be driven off from calcite or limestone by a stronger acid, such as hydrochloric (muriatic) acid, nitric acid, or even strong vinegar. In this case what remains is not lime, but a compound of lime with a part of the acid. If a drop of acid, which (if hydrochloric or nitric) ought to be diluted, is placed upon calcite or limestone, a brisk boiling or bubbling takes place at once in the drop, owing to

the escape of the carbonic acid gas. This boiling is called *effervescence*. The experiment is a simple and useful test by which calcite may be distinguished from a number of minerals which it resembles. It will, for example, distinguish calcite from quartz or gypsum; it *effervesces* with an acid, while they do not.

95. Calcite is dissolved to a limited extent in water containing free carbonic acid. Rain water, in passing through the air, absorbs some carbonic acid, and acquires the power of dissolving limestone. Such water, passing through the soil and coming in contact with limestone, or other calcareous material, dissolves some of it, and when it issues in springs from the rocks or soils, it is *hard* or *limestone water*. A vast amount of limestone rock is thus dissolved and carried away every year by the water of springs.

96. Caves.—The caves so common in limestone regions owe their origin in most cases to the action of rain water containing carbonic acid. This gets into the cracks and fissures of the rocks, and dissolves out a way for the water to run; thus an underground stream is formed. Such streams, once started, not only dissolve the rock, but wear and scour it away with the sand and mud which they often carry along. Thus large and long subterranean caverns have been excavated, like the *Big Bone*, and other caves in Tennessee, and the *Mammoth Cave* in Kentucky.

97. Stalactites and Stalagmites.—The rain water which trickles down through the cracks and fissures in the roofs of caves contains dissolved limestone; it brings a load of limestone or calcite with it. Upon reaching the ceiling of the cave, a part of the water is evaporated, and calcite is deposited upon the ceiling. In this way *stalactites*, to which we have already referred, are commenced, and are made to increase. There may be nothing but a little knot or nipple of matter to begin with, but by continual ad-

ditions the stalactite may become very large and long. Some of the water falls to the floor of the cave, and evaporating there, deposits calcite. Thus it is that stump-like piles of calcareous matter are built up, which are known as *stalagmites*. A stalactite often has a stalagmite directly under it. The first lengthens downward from the ceiling, and the other upward from the floor. They often meet, and form a column, or pillar, in the cave.

98. The waters of springs and rivers sometimes deposit calcite from solution in considerable beds. When these are extensive and compact, the material is known as *travertine;* when cellular, as *calc*, or *calcareous tufa*. These are of the same nature as stalactite and stalagmite material. Calcareous tufa often contains twigs, leaves, moss, etc., which have become enveloped by the deposition of the calcareous matter around them. Travertine is frequently used as marble, and some varieties are very handsome.

III.—DOLOMITE.

99. Compared with Calcite. Magnesian Limestone.—Dolomite is much like calcite, from which it is not always easily distinguished. It is harder than calcite, and does not effervesce freely unless the acid is heated. As to chemical constitution, dolomite not only contains *lime*, but *magnesia* also; so that while calcite is simply carbonate of lime, dolomite is *carbonate of lime and magnesia*. Dolomite is often burned for lime; when it is, the lime produced is necessarily mixed with magnesia.

100. In rock masses this mineral is called *magnesian limestone*. Great strata of it, many hundred feet

thick, exist in Tennessee, especially in the eastern part of the State. The higher and greater part of Knoxville is built upon this rock. (§ 45, p. 30.)

IV.—Feldspar.

101. Composition and Kinds.—This is one of the minerals which helps to form granite and granite-like rocks. Within Tennessee it is only to be found in the rocks of the Unaka Range. There are several varieties of feldspar, or rather, feldspar is the name of a *group* of minerals. They are all silicates of alumina, combined, in addition, with some other alkaline substance (p. 46). One variety, *orthoclase,* already mentioned as a member of the scale of hardness, contains potash, and is, therefore, a *silicate of alumina and potash* — a *potash-feldspar.* This is common feldspar. Another contains soda in the place of potash, and is known as *soda-feldspar* or *albite.* Others contain both soda and lime, and are *soda-and-lime-feldspars,* one of which is known as *labradorite.* These minerals have about the same weight as quartz and calcite.

102. Distinguished from Quartz.—The feldspars may be distinguished from quartz by the following characteristics:

They are not so hard by one degree, though they cannot be scratched by the knife; they melt when exposed to high heat; and they break or split in two directions, in one direction splitting easily, and giving an even, bright, and polished surface.

103. This property of splitting in one or more directions, with bright, even surfaces, is called *cleavage* by mineralogists. Very many minerals show it. We have spoken of the cleavage of calcite on page 50. Quartz does not ordinarily show cleavage.

104. Source of Clay.—The feldspars are important minerals. It is from them principally that the characteristic ingredient of different clays has been, and is derived.

The pure clays are *hydrous* (containing water) *silicates of alumina.* When feldspars, or the rocks containing them, decompose, they lose much of their *basic* part, that is, their potash, soda, lime, etc., becoming simply silicates of alumina, or clays. *Kaolin,* or china clay, is one of the purest of the clays. It is found in regions where granite-like rocks are decomposing. The best china ware, or porcelain, is made from it.

Common clays are mixtures, and contain sand, oxide of iron, and minute particles of other minerals derived from various rocks.

V.—Mica.

105. Characteristics, Uses, etc.—This mineral, sometimes improperly called *isinglass,* is easily recognized by its splitting or cleaving into *exceedingly thin* and elastic leaves. It is often seen in granite, sandstones, and other rocks, in minute silvery, and sometimes shining black, scales. It is one of the trio of minerals which compose ordinary granite, quartz and feldspar being the others. When the granite is coarse the leaves of mica are large, and may be mined. There is a mica mine in North Carolina. Mica leaves stand the fire well, and are used for a variety of

purposes, one of which is to make windows in stoves, so that the fire may be seen.

106. Mica is generally transparent, or translucent, and may be white, gray, brown, or black. It is not quite as hard as calcite. It is, like feldspar, a *silicate of alumina*, combined in various proportions with alkaline or basic substances, principally potash, magnesia, and oxide of iron. Some varieties contain water as an ingredient.

VI.—Amphibole and Pyroxene.

107. Common Characteristics.—These minerals have the same composition. They are silicates of two or more of the following bases: lime, magnesia, oxide of iron, and alumina. Rarely, certain other bases occur. Lime and magnesia are generally present in the different varieties, of which there are very many; iron and alumina exist in addition in particular varieties. Amphibole (am′-phi-bole) and pyroxene (pyr′-ox-ene) are often distinguished with difficulty unless in crystals, the shapes of which are unlike. In their different varieties they vary in color from white, through shades of green, to black. They may be in crystals or crystalline masses, or in grains, leaves, or fibres. Some of the fine, fibrous, or silky kinds of both are called *asbestus*. These minerals vary in hardness from 5 to 6½, and are, therefore, not as hard as quartz. They are from three to three and a half times as heavy as water.

108. Amphibole.—This is often called *hornblende*, but we confine this name to the dark-green or black varieties; hornblende contains iron and alumina. It frequently takes the place of mica in granite and allied rocks, and this is the only difference between granite and *syenyte*. It often looks like mica in the rocks, but it is brittle, and will not split into thin, elastic scales with the point of a knife, as mica does.

109. Pyroxene.—A greenish variety of this mineral, called *sahlite*, is found in Tennessee. It is associated with the magnetic iron ore of Carter county. *Augite* is a black or blackish-green variety, looking like hornblende. It contains iron, and is common in rocks of igneous origin.

VII.—Garnet.

110. Characteristics.—Beautiful, many-sided, dark-red crystals

of garnet occur imbedded in mica slates, and other rocks. They may be found in the region of the copper mines at Ducktown.

Fig. 6.

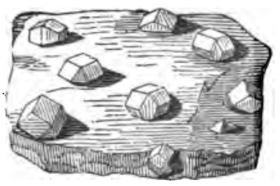


Fig. 6 shows the manner of their occurrence, as well as how they project out on the surface when the rock has been worn away by the weather. The crystals are of all sizes, from that of a pin's head to forms an inch or more through.

This mineral is also a *silicate*, containing alumina, iron, and lime. It is variable in hardness, but averages about that of quartz. When found in well colored and clear crystals it is used as a gem.

111. *Tourmaline* is another mineral which is found imbedded in rocks. It occurs usually in long, black, brilliant prisms. Sometimes its crystals are beautifully red or green. The red variety is occasionally used to imitate rubies. Tourmaline is a *silicate* much like the others, but differs in containing *boracic acid*, one of the ingedients of common borax.

VIII.—Talc and Chlorite.

112. Talc.—This is one of the softest of minerals. It represents 1 in the scale of hardness (p. 47). It is unctuous or soapy to the touch, so much so that the powder is sometimes used, like grease and graphite (p. 49), as a lubricator. It is not unfrequently called *soapstone*. It is greenish, white, red, or gray, and has a pearly hue or lustre. One variety splits into thin leaves like mica, but the leaves are not elastic; they bend, but do not fly back, which serves to distinguish them from mica. Talc is a silicate of magnesia containing water.

Steatite is an earthy, compact variety of this mineral. It is sawn into slabs and used for lining fur-

naces and stoves as a protection against the heat, and has also other uses. It is mined in North Carolina. Talc has very nearly the weight of quartz, bulk for bulk.

113. Chlorite, or Prochlorite.—Chlorite is much like talc, and sometimes the two are not easily distinguished. It is slightly harder than talc, not so unctuous to the touch, and generally of a darker green color. It contains also alumina, in addition to the other ingredients of talc.

Both of these minerals enter largely into the composition of rocks. They form *talcose* and *chloritic* slates.

114. Serpentine.—Like talc, serpentine is a hydrous silicate of magnesia. It is, however, a different mineral. Its average hardness is about that of calcite, with which it is sometimes associated as a massive rock. This rock sawed into slabs makes a much-admired marble called *verd-antique* or *serpentine* marble. The serpentine may be green, yellow, or red, and with the white calcite it makes a mottled or clouded surface, often of great beauty.

CHAPTER VIII.

The Kinds of Rocks.

115. In the last chapter we considered the kinds of minerals which, with a few unimportant exceptions, make up the rocks of Tennessee. In this we study the rocks themselves as to kind and mineral composition

116. Rocks are generally mixtures or aggregations of minerals which may be in minute or coarse grains, in pebbles or in small crystalline pieces. How this is will be better understood after considering

117. The Origin of Tennessee Rocks.—These rocks were once beds of gravel, sand, calcareous and clayey muds at the bottom of the ocean, which, at certain times in past ages, covered the whole of Tennessee, and at other times but parts of it. The gravel, sand, and mud were derived from a variety of sources. They were washings from the lands, or matter drifted from one part of the ocean to another, or accumulations of shells, corals, and other remains of animals and plants, broken, or even ground, to mud by the currents. The beds, by the pressure of the waters and their own weight, became compact, and finally, through simple cohesion or the action of cementing substances, hardened into rock. Thus the pebbles became conglomerates; the sands, sandstones; the clays, shales; the calcareous mud, limestones.

118. Deposits of materials like those which ages ago gave origin to the rocks of Tennessee, are at this day accumulating and hardening, more or less, into rock in the oceans and seas, and some of them may in time to come *be raised out of the sea, as our rocks have been,* to form the foundations of new lands for future generations.

119. It must be stated, however, that, so far as the *hardening* of the beds is concerned, the greater

part of *West Tennessee* presents an exception. Here the strata are *unconsolidated* beds of sand, clay, etc. These sands and clays were deposited, like the others (but long afterward), at the bottom of the ocean, or rather in this case, of an arm of the ocean, which reached up as far north as the mouth of the Ohio river. This arm was an extension of what is now the Gulf of Mexico. Such strata as those of West Tennessee, although not hardened, are, nevertheless, called *rocks* by geologists.

120. But it must not be understood that the deposits which were the beginnings of our rocks were beds of pure sand, clay, etc. Washings from the lands and drifts in the ocean would contain every thing movable by floods or currents. The different mineral matters would be sorted out to some extent by the flowing water, so that here pebbles would predominate; there sand; and beyond, clay. But yet this sorting would not be complete, each kind would generally contain more or less of the others. It thus happens that sands and sandstones often contain clay, calcareous matter, grains of mica, and other minerals. We call it sandstone when the sand predominates and gives character to the mass. Limestones are rarely pure calcareous matter; they may contain sand, clay, and other ingredients in various proportions. This is one reason why we have so many varieties of limestone. And so with the other rocks.

121. The rocks in general may be grouped into three classes—the *sedimentary*, the *metamorphic*, and the *igneous.*

122. I. Sedimentary Rocks and the Terms Applied to them.—The beds of sand, clay, etc., of which we have spoken, and similar deposits, are often called *sediments*, and the rocks resulting from them *sedimentary* rocks. The term *fragmental* is also applied to them, for the reason that the particles from which they are made are *fragments* from still older rocks. They are also called *stratified* rocks, as the materials of the sediments were spread out in layers one above another. Many of them contain *fossils*, and are, therefore, termed *fossiliferous* or *fossil-bearing* rocks.

123. II. Metamorphic Rocks.—*Metamorphic* means *changed*. In some regions sedimentary rocks have been so acted upon by long-continued (but not a melting) subterranean heat as to have changed in mineral character. The water-worn particles or fragments originally composing them are seen, if large enough to be visible, to have become crystalline grains. Very often, under the influence of the heat, the elements of the particles react upon each other in such ways as to produce crystalline grains of minerals very different from the species of minerals to which the particles belonged. By such changes impure sandstones and clayey rocks have been, in some regions, transformed into granite-like rocks wholly different in appearance; dark and purer limestones into white statuary marble; and soft shales into tough roofing slates. Rocks thus changed are known as *metamorphic* rocks. Many of the strata of the Unaka Range are of this character.

Sometimes metamorphic rocks show no distinct crystallization, the change consisting in a greater hardening of the original mass.

124. III. Igneous Rocks.—The rocks so named have been in a melted state. They occur in what were once openings or fissures in the earth. The fluid rock coming up from some seat of fires below, filled the fissures and solidified in them. In this way a class of *veins* have been formed which are called *dikes*. A few dikes have been observed in the rocks of the Unaka Range, but they are of little importance. In volcanic regions igneous rocks are common, and occur in dikes and beds, the latter resulting from the overflow of lava from volcanic vents or craters.

We will now enumerate and briefly describe the kinds of rocks occurring in Tennessee.

125. (*a*.) **Sandstones and Related Rocks.**—These are sedimentary rocks, and were once beds of sand, or gravel. The characteristic mineral is quartz, though particles of other minerals are often present. Sandstone is one of our most common rocks. It occurs in many parts of the State, and in most of the formations. It may be fine- or coarse-grained, and of a variety of dull colors, white, grey, brown or red. When hard and rough, it is sometimes called a *grit;* if containing clay or earthy matter, it is *argillaceous sandstone, argilla* being the Latin word for *clay.*

In the Unaka Range sandstones are met with which are hard, very compact, gray or white, and consist of quartz grains. These are sometimes called *quartzytes.* They are either partly or wholly metamorphic rocks. Some varieties contain scales of mica.

126. Pebbles and Breccia.—A bed of gravel which consists of rounded pebbles mixed with sand, when consolidated into rock, is called a *conglomerate* or *pudding stone.* If the gravel contains angular (not rounded) fragments, the rock resulting is *breccia* (bret′-cha). The pebbles, or angular fragments, are not always quartz. Sometimes they are limestone (calcite), or of other kinds. If principally quartz, the rock is *siliceous conglomerate,* or *siliceous breccia,* as the case may be; if of limestone, *calcareous* or *limestone conglomerate,* etc. If the pebbles or fragments are cemented together with iron-ore, the rocks are said to be *ferruginous,* a term derived from a Latin word which means *of iron,* or *containing iron.*

Sandstones and quartz-rocks are also spoken of on page 46, to which the student is referred.

127. (*b*.) **Limestones.**—Common limestones are well known. The characteristic mineral contained in them

is *calcite*, and hence they are said, as stated on page 50, to be *calcareous* rocks.

There are many varieties of limestones. They may be coarse- or fine-grained, hard or soft, pure or impure, as before explained; they may contain shells, entire or broken, crinoids, corals, fish-teeth, bones, or other relics of extinct races. They are generally dull-blue, or gray, but may be colored, by the impurities present, yellow, red, brown, and even black.

128. The following are common varieties:

Argillaceous limestone. Containing clay.

Siliceous limestone. Containing fine sand, or siliceous particles.

Cherty limestone. A limestone more or less mixed with the kind of flint called *chert*, which is present in particles, lumps, or layers.

Oolytic limestone or *Egg-limestone.* Made up of small round particles (concretions), from the size of a mustard-seed to that of a pea, and looking like a mass of petrified fish-eggs. *Oolyte* is derived from a Greek word meaning egg.

Shell-limestone and *Fossiliferous limestone.* Containing animal remains.

Chalk. An earthy limestone, generally white, easily making a mark on wood, or other hard substance.

Hydraulic limestone. An impure limestone that burns into a kind of lime which hardens under water; it is also called *cement-limestone* and *water-lime rock.*

Marl. An earthy mass containing much soft or powdery limestone.

Marble. Any limestone that is durable, takes a good polish, and looks well when polished, may be called *marble*. The marbles of Tennessee will be treated of in the Economic Part.

129. If not too impure, limestones burn easily into lime. Sometimes, when containing much sand, flint, or clay, they burn into lime with difficulty; they are

then called *fire-rocks* in Tennessee, and are used for hearths, and the backs of fire-places.

130. The limestones of this State belong to the *sedimentary* class. In North Carolina, not far from the Tennessee line, limestones exist which have been changed by heat into more crystalline, compact, and generally lighter colored, rocks, or, in other words, are of the *metamorphic* class. Some of these make good marbles.

131. The calcareous matter out of which the *stalactites* of the caves are formed (pp. 52, 53), is another kind of limestone not included above. It differs in having once been *dissolved in water*, as already explained, while common limestones were at one time beds of calcareous mud or sediment that have since consolidated into rock.

132. (*c.*) **Magnesian Limestone, or Dolomite.**—This rock is much like limestone, and is often so called. It has been sufficiently described under *dolomite considered as a mineral* (p. 53).

133. (*d.*) **Iron-ore Rocks.**—The *dyestone ore* of Tennessee (p. 183) is a stratified rock. It appears to have been once a mixture of limestone and carbonate of iron (*a double carbonate*). The part worked for iron has had the limestone leached out of it by the action of water, and has been further decomposed, so that now it is mainly a red *hematite*. Other beds of hematite in East Tennessee, and the *magnetite* of Carter county, are also rocks. For descriptions see Economic Part.

134. (*e.*) **Shale.** — This is another very common rock. Shales are hardened beds of clay; some shales are little else than clay arranged in thin laminæ or leaves. They belong to the sedimentary class. Shale is often improperly called *slate*, especially if splitting into plates a foot square or more. There is, however,

no true slate anywhere in Tennessee east of the Unaka Range, where the metamorphic rocks are found. The rocks so called are shales.

Shale is a soft rock, splitting or separating, like slates, into thin leaves, which are generally fragile or easily broken, but sometimes quite tough. It may be gray, greenish, purplish, reddish, and even black. The following are included among the varieties:

135. Bituminous Shale.—A shale containing *bitumen* or coaly matter, and sometimes yielding crude coal-oil, or kerosene, when heated in a still. It is generally black, and when put on hot coals often flames for a little while, but does not burn to ashes. It is often mistaken for coal. Bitumen is a sort of natural pitch, or hardened tar.

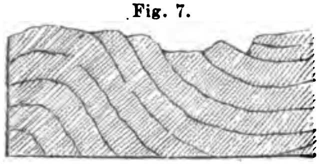
136. Alum Shale.—A shale from which alum may be manufactured. It contains alum, or iron *pyrite* (p. 197).

137. (*f.*) **Slate.**—The true slates are rocks which have been changed by heat, and belong, therefore, to the metamorphic class. They are slaty in structure, being made up of laminæ of greater or less thickness. The slates, as we have said, and all the rocks that remain to be described, are confined to the Unaka Range, the metamorphic area. Some of the principal kinds are:

138. CLAY SLATE, OR ARGILLYTE.—*Roofing slate* and *writing slate* are good examples of this kind. Clay slate, or argillyte, is a slaty rock of fine grain, and of various, but usually dull, colors, such as gray, green, red, purple and black. It must split evenly to make good roofing and writing slates. Slabs of it are used for table-tops and for mantles. It is usually a mixture of very fine quartz and feldspar. This rock differs from

shale, among other things, in the direction in which it splits. Shale splits in a plane parallel to the top and bottom of the bed or stratum to which it belongs, while slate splits independently of the bedding, and may split, directly or diagonally, across the bed. The cut, Fig. 7, illustrates this. The strata, which in this case are curved, are marked out by the curved and darker lines; the slates by the finer straight and diagonal lines. It is seen that the slates run in a determinate direction without reference to the bedding. This kind of splitting is called *slaty cleavage.*

Fig. 7.



Argillyte not unfrequently contains, imbedded in it, crystals of pyrite, garnet, and other minerals.

139. Mica Schist.—*Schist* is another name for slate. The name is applied to a slaty rock mostly made up of visible, glistening scales of mica. Mica schist is very slaty in structure, breaking into thin pieces, and often easily wearing away. Besides the mica, it contains a little feldspar and more quartz. Like argillyte, it often contains imbedded crystals.

140. Mica Slate.—This is like mica schist, excepting that the scales of mica are so small as hardly to be seen without a magnifying glass.

141. Hydro-mica Slate.—Similar in character to mica schist and mica slate; but the mica is *hydrous,* that is, contains water in composition, which gives the rock a more or less greasy feel and pearly look. It was once called *talcose slate,* the hydrous mica being taken for talc.

It may be added here, that there is a true *talcose slate,* but it occurs rarely and in local beds. *Steatite,* or *soapstone,* is a rock-form of talc, unmixed with other minerals (p. 57).

142. (*g.*) **Granite.**—This rock, in some countries, forms great mountain masses. In Tennessee there is very little of it, the rock so-called being *gneiss,* which is described below. It differs from all the rocks we have mentioned in not occurring in beds or layers;

it is a massive, *unstratified* rock. Granite, as before stated, is composed of *quartz*, *feldspar*, and *mica*, minerals that have been studied. These exist in granite, not in rounded grains or in pebbles, such as make up sandstones and conglomerates, but in crystalline grains, those of feldspar and mica often showing smooth and shining faces. The grains are promiscuously mixed together. The crystalline character is the result of heat.

143. Granite is of motley color, each of its minerals having usually a different tint. On broken, or better, polished surfaces, the quartz grains or portions, in a given specimen, may show spots of either gray or smoke-color; the feldspar, white or flesh-red; and the mica, white or brown, or even black.

144. (*h.*) **Syenyte.**—When a granite-like rock has the mineral *hornblende* in it, in the place of mica, it is called *syenyte*.

The hornblende in syenyte is generally dark-colored, or black, sometimes grayish- or greenish-black. Its grains are brittle, and will not split into thin, flexible scales like mica. In this way it may be distinguished from black mica. This suggests a way of determining whether a given rock is granite or syenyte.

The red Scotch granite brought to this country for monuments is syenyte.

Unakyte is a coarse granite in which a greenish mineral, called *epidote*, replaces mica. This rock is found on the North Carolina line, in Cocke county, Tennessee, at a place called the "Bluff." It has been named *Unakyte*, by Prof. Bradley, because it occurs in the Unaka mountains.

145. (*h.*) **Gneiss.** Gneiss (pronounced like the

word *nice*), is the same as granite, excepting that it occurs in beds or layers, and looks like a stratified rock. It has been called *stratified granite.* It occurs in layers, because the minerals composing it, especially the mica, are arranged in planes. The rock will sometimes break rather easily into slabs or flags. Many of the high mountains of the Unaka Range, near and on the North Carolina line, are made up of gneiss and gneissoid (nice-soid) rocks.

146. Gneiss passes into *mica schist* or *mica slate* when the amount of mica present becomes great in proportion to the feldspar and quartz, the other ingredients of the rock.

In gneiss, mica schist, and mica slate, as in granite, the mica may be replaced by hornblende. Hence we have *hornblende gneiss, hornblende schist,* and *hornblende slate.*

Protogine is a sort of granite or gneiss containing *chlorite* (or *talc*) in place of all, or some, of the mica.

Many of the mountains near and on the North Carolina line are made up of gneiss and gneissoid rocks, principally of the mica and hornblende kinds.

147. The rocks just described, commencing with *slate,* are included in the metamorphic series. Granite occurs sometimes in veins, and *appears* to have filled fissures (p. 61) in a melted state. Such granite has been called an *igneous* rock, but the matter of which it is composed may have been brought into the fissures through the agency of heated waters, or in some other way.

148. (*i.*) **Trap Rocks.** — These are igneous rocks which, with the *lavas,* as before remarked, are, so far

as the Geology of Tennessee is concerned, comparatively unimportant.

Trap (from *trappa*, step) is a heavy, dark-colored rock, often found in *dikes*, or filling what were once fissures in the crust of the earth. It entered these fissures, from fiery depths, when in a melted state (p. 61).

Dikes are met with in many regions where there are no volcanoes, so that trap is not necessarily a *volcanic* rock. It consists of a *lime-soda feldspar* (called, from *Labrador*, where it was first found, *labradorite*). and *augite* (pyroxene). It also contains grains of magnetic iron-ore. The rock is crystalline in texture, but sometimes very finely so, being hard and compact.

149. Trap is the rock of the long bold cliff on the west side of the Hudson river, just above the city of New York, and well known to travelers as the *Palisades*. Dikes of trap make many ridges in the states bordering on the Atlantic from Massachusetts to North Carolina, as well as the region of Lake Superior. It is the rock of the Giant's Causeway in Ireland, and of Fingal's cave in the isle of Staffa, illustrations of which places are often seen in school geographies.

150. *Doleryte* and *Basalt* are names applied to trap rocks; basalt especially to the fine-grained varieties.

151. *Dioryte* (Greenstone) is a trap-like rock, composed of a soda feldspar, or a soda-lime feldspar and hornblende.

152. *Amygdaloid*, or *Almond-rock*, is a trap containing, imbedded in it, nodules of different minerals. The places filled by the nodules were originally cavities in the trap made by the gases, when the rock was still melted. Sometimes the nodules have the shape of almonds, hence the name of the rock, *amygdalum* being the Latin word for *almond*.

153. Porphyry. — Any rock containing distinct crystals of feldspar scattered through it is said to be *porphyritic*. A polished surface of such a rock shows angular spots on a ground of different color. True *porphyry* has both spots and ground of feldspar, though differently colored. It consists of compact feldspar, through which are disseminated crystals of the same mineral.

154. (*j*.) **Lavas, or Volcanic Rocks.**—The rocks so named have been formed by the action of volcanoes. These fire-mountains eject melted rock from their craters, and sometimes from fissures and openings on their sides. The melted matter cools and hardens into lava of different kinds.

The lavas are much like trap in composition. They are often cellular in structure, and many of them resemble slags from furnaces.

155. *Trachyte* (from a Greek word meaning rough) is a common lava, which, when broken, shows a rough surface. Another variety, *scoria*, is light and spongy. *Pumice* is also spongy, but the cells are long and the rock fibrous in appearance. Pumice is from an Italian word, meaning *froth*. It is usually of a whitish-gray color, and is extensively used for scouring and polishing wood, stone, metal, glass, etc. *Obsidian* is a volcanic glass, formed by the rapid cooling of certain kinds of melted lava.

CHAPTER IX.

The Forms of Occurrence, Position, Denudation, and Fossil Remains of the Rock-masses. Geological Theory of the Earth.

156. Having considered the kinds of rocks, our object now will be to learn in what forms the rocks occur, or are arranged, in the mountains and hills, and under the valleys; whether in layers or in unstratified masses; if in layers, how these lie, whether horizontal, inclined, or folded. We propose, further, to learn something about the enormous wear or denudation which the rocks have suffered through the action of water and other agencies. The world is a very old, greatly worn, and weather-beaten one. We shall also inquire into the character of the remains of animals and plants, which are found imbedded in the rocks. And lastly, we shall notice the theory which geologists have proposed in order to account for the form of the earth, and for the existence and general character of its rocky exterior.

I.—Forms in which Rocks Occur.

157. Forms and Classifications.—There are three forms in which the rocks occur: (*a.*) the *Stratified;* (*b.*) the *Unstratified;* (*c.*) the *Vein-form.*

158. This is a classification of the rocks, based on their forms as actually seen in cliffs, ledges, quarries, veins, wells, and other exposures, without especial reference to the theories of their origin, or to the agents concerned in forming them, though these may be noticed in the descriptions.

The *first* classification given, that on pp. 60, 61, in which the rocks are grouped into the three classes, *sedimentary*, *metamorphic*, and *igneous*, is different, and has direct reference to these agents, and especially to the two

great and, in some respects, opposing agents, *water* and *heat* (or *fire*), which, more than all others, have been instrumental in building up, changing, destroying, and rebuilding the rocks of the earth. The sedimentary rocks, as we have learned, have been formed by the agency of *water;* the metamorphic, by that of *water and heat;* the igneous, by *heat*, or *fire*.

159. (*a.*) THE STRATIFIED FORMS. *Definitions.*—Rocks are stratified when they lie in layers, beds, or strata, one upon another.

160. The student must know the meanings we attach, respectively, to the terms *layer*, *stratum*, and *formation*, and how they differ.

A *layer* is one of the beds or leaves into which a rock is ultimately and naturally divisible. It may be many feet thick, or as thin as a writing-slate.

A *stratum* is a collection of layers of the *same kind*, no matter how thick. The top or bottom of a stratum is reached when we meet with a layer of another kind of rock. (A single layer, which has a different rock both above and below it, is also a stratum.) The word *stratum* is defined on page 4, which see. (It is pronounced stray′-tum, the plural being *stray′-tah;* not strat-um and strat-a.)

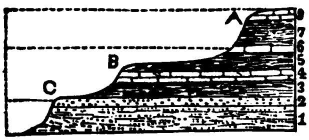
A *formation* embraces all of a series of strata formed in *one age*, or *one period*, of time. See further page 4.

161. Very nearly all the rocks of Tennessee are stratified. The fact that the rocks show themselves in layers must be familiar to every boy or girl who knows how to observe. It is well seen in the bluffs (cliffs) along the rivers; limestones, sandstones, and other rocks are quarried out *in layers* of different thicknesses; *layers* of rock are seen in the beds of creeks, in railroad cuts, and often outcrop on the hillsides. Many rocks, as the shales, slates, and schists we have studied, are made up of layers so thin as to be called *slaty*.

162. The annexed figure (taken, with others which follow, from Mr. Dana's great work, the *Manual of Geology*), may be used as an illustration of how the layers and strata of rock show their edges, or *outcrop*, on the face of a bluff.

In the particular series of strata represented, 1, at the bottom, is a stratum of sandstone; 2 is a hard gray layer, called *Gray Band;* 3, a thick bed of greenish shale; 4, a limestone; 5, another bed of greenish shale; 6, another stratum of limestone; 7, shale again; 8, at the top, another limestone, different from those below. The thickness of the whole is 400 feet.

Fig. 8.



163. Such an exhibition of the rocks is called a *section.* The cut represents a *section* of the strata exposed along the Genesee river at the falls near Rochester, New York. Wherever the rocks are cut into, or through, by streams, railroads, or in mining, sections of the layers or strata are exhibited.

The part of the cut, on page 77, showing the edges of the strata, *a*, *b*, *c*, etc., is a great cliff, and gives a good idea of what is meant by a section in geology.

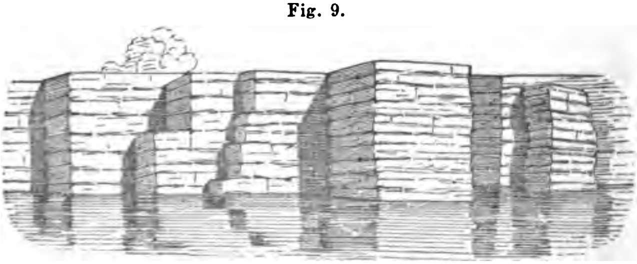
164. In the deep gorges of mountain streams, the sections presented are sometimes thousands of feet high. The *Colorado river*, on the west slope of the Rocky Mountains, has, for 200 miles of its course, cut its way down through the strata for hundreds, and even thousands, of feet. Looking up from the river, the cliffs rise, on both sides, in vertical walls from 3,000 to 6,000 feet in height. The layers and strata are well exposed in these cliffs, and on so large a scale, that geologists delight to visit them

In our own State, the grand cuts formed by the rivers intersecting the Unaka Range, and spoken of on pages 26 and 27, give sections of the rocks hundreds of feet high. The Cumberland Table-land also has many gorges (*gulfs*, we sometimes call them), worked out by the streams, and exposing the strata which build it up. The strata of the Highland Rim are exposed in a similar manner. Many of the streams which flow from this Division have cut out, in their descent into the Central Basin, deep gorges bounded by high bold cliffs. At the heads of the gorges are often beautiful, and even grand, water-falls. Those of the Caney Fork and its tributaries are especially noted.

165. Thus it is seen that the water-courses, rivers, and creeks, have been of great service to geologists in laying open and displaying the rocks. It was mostly by the careful study of such sections that the formations of Tennessee were made out.

166. Horizontal Position of Layers, or Strata.—The figure on the last page represents the outcropping edges of *horizontal* or *level* strata. The sketch on this page

Fig. 9.



is a good picture of such strata. The stratified rocks have this position over very large areas of North and South America, and the other continents of the globe. The rocks of more than two-thirds of Tennessee vary but little (with few local exceptions) from a horizontal

position. The part of the State thus having horizontal rocks, commences with the western half of the Cumberland Table-land, and extends to the Mississippi river, which includes all of Middle and West Tennessee.

167. In addition to the horizontal position, the sketch shows what is meant by *jointed structure.* It is not uncommon to find the rocks of a region thus divided into very regular angular blocks by cracks which run down to great depths. The cracks are called *joints.*

168. Extent of Strata.—In connection with the horizontal position, it will be well to notice the horizontal *extent* of the strata, or how far they spread out. These sheets of rock, in some cases, extend short distances, in others many, and even hundreds, of miles.

169. As an example of their great extent, the *Black Shale* may be given, one of our best known formations, and one which has often been mistaken as an indication of coal, or even for coal itself. This formation, which, for the most part, is a single stratum of blackish, bituminous shale (usually called *slate*), not at any point in Tennessee much over 100 feet in thickness, is found in the western part of the State outcropping along the hills on both sides of the Tennessee river. Going eastward, it appears again all around the slopes of the Central Basin; thence spreads under the Cumberland Table-land; re-appears at the eastern slope of this division, outcropping along its base, from Georgia to Virginia. It thus reaches, though comparatively so thin, for more than 200 miles through the State, always having the same relative position, so far as the formations above and below it are concerned. But this is not all; this *Black Shale* reaches beyond Tennessee, extending in a northerly direction to the lakes, and in a southerly far into Alabama. It may be seen at Blourt Springs, in the latter State, presenting the same appearance that it does in Middle and East Tennessee.

170. Original Position of Strata. — All the strata in Tennessee were once horizontal, or nearly horizontal. That it must have been so will be plain when we consider their origin. As stated in paragraph 117, on page 59, the strata were at first beds of sand, clay, mud, etc., in the ocean. The materials of these, derived, during very long periods, from various sources, were, by the action of currents and the waves, spread out in layers over the nearly level bottom. Hence the horizontal position of the strata.

171. Folded and Inclined Strata; Formation of Mountain Ranges.—After the strata were formed, as above stated, they were raised, *very slowly* and in great and wide masses, out of the ocean to make the continents. Over large areas they retained mostly their horizontal position, but over other areas they early began (in consequence of great *lateral pressure*) to *wrinkle* in a succession of immense folds, which, in many cases, ended in the upturning of the rocks, and in the formation of mountain ranges. By this action the strata were crowded together, often broken, made to overlap, and *to dip* or be inclined at all angles. Such wrinkling or folding of the rocks has happened at different periods in the history of the world, the mountains resulting being of different ages. The Appalachian Belt of mountains and valleys (page 11) originated in a system of folds completed in one of these periods; the Rocky mountains in a system belonging to another and a later period.

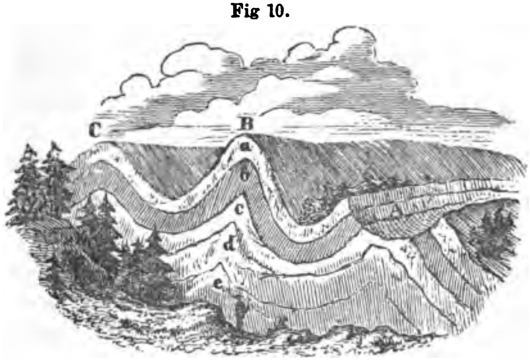
172. Lateral Pressure; Illustrated in an Apple. — The folds of the strata may be compared, in some respects, to the wrinkles on a drying apple. As the pulp of the apple dries it contracts, while the rind or skin does not. Thus the rind becomes too large for the pulp, and as it does not separate from the pulp, it is drawn or pressed together laterally until its superabundant part rises in wrinkles. The earth, like the apple, has two parts, a *crust*, and an inside part which is contracting. In one case the contraction is due to drying; in the other, to cooling from a heated condition, but the effects of contraction in the two cases are, in

some degree, analogous. The outer cool and hard crust of the earth does not contract, and hence becomes too large for the heated and cooling interior. Its mass, like the parts of an arch, press laterally together until finally the crust relieves itself by forming one or more folds along some weak and yielding portion. Owing, perhaps, to the presence of melted, and hence fluid or plastic rock below, the strata generally begin the folding by a downward movement.

173. The layers of rock, although appearing so stiff and inflexible, will, under certain conditions, bend to a considerable extent. Like piles of thick cloth, if pressed together from opposite sides (lateral pressure), they will arrange themselves in folds (*plaits* we call them on page 41).

174. Sections of Folds, etc.—The cut, Fig. 10, taken from Lyell's Elementary Geology, illustrates well how strata may be folded, and how mountains may result. It was intended to illustrate the structure of the Swiss Jura mountains, but it illustrates as well the structure of some of the Appalachian mountains and valleys of Tennessee.

Fig 10.

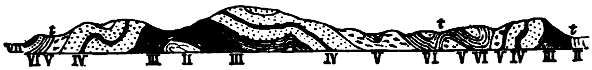


The letters *a*, *b*, *c*, *d*, and *e*, represent strata or formations which, by lateral pressure, have been crowded up into the folds, A, B, and C. Both B and C are unbroken and *undenuded*, forming long, straight mountain ridges. A, however, has been fractured and denuded along its summit, a trough or valley resulting along the line of elevation.

Sequatchee Valley, in this State, has the same structure as the trough A. It also has been washed out along the back of a fold.

Fig. 11 represents the folding of the strata in one part of the Appalachian belt, as observed in Virginia. The groups of rocks are indicated

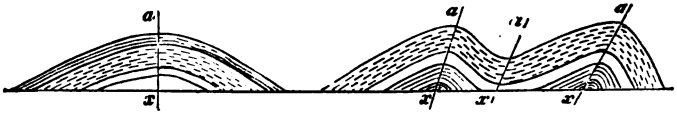
Fig. 11.



respectively by the Roman numerals. Although the folds are not complete, the student will be able, doubtless, to trace them out.

175. The names applied to the different parts of a fold are explained in Fig. 12.

Fig. 12.



An imaginary plane dividing a fold lengthwise, and indicated by $a\ x$, is the *axis* of the fold. It is an *anticlinal axis* when the strata slope away from the plane in opposite directions, like the two sides of a roof. The strata of an *anticlinal ridge* slope in this way. It is a *synclinal axis* when the strata slope *toward* the plane from opposite directions, like the sides of trough or the letter V. In Fig. 12 $a'\ x'$ is a *synclinal axis*, and the valley under a' is a *synclinal valley*.

Folds, like those above, that have had their tops removed (denuded) are sometimes called *decapitated* folds. In the annexed Figs., 13 and 14, if the fold a has its top removed it becomes like b. The removal of the top leaves the strata dipping in one direction, and arranged in the order represented by the figures 1, 2, 3, etc. This order will be referred to again.

Fig. 13.

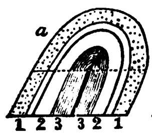
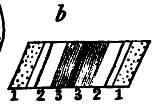


Fig. 14.

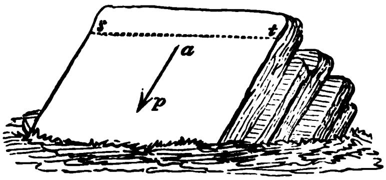


The left part of Fig. 11 shows a decapitated fold. The strata have been so removed as to form a valley along the back of the fold; and this valley is *anticlinal* in character, since the strata slope away from the axis. On each side of the valley is a ridge. The relations of the strata at the bottom, and on the opposite sides of the valley, the way in which they outcrop and dip, are clearly presented.

176. Outcrop, Dip, and Strike.—These are words often heard from the lips of a geologist, and they are very important ones in his vocabulary. The first two we have already used a number of times.

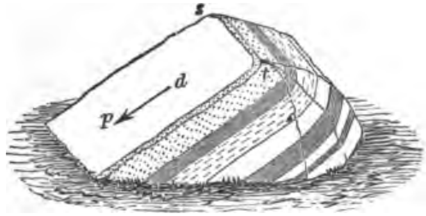
A rock *outcrops* when it projects out of the ground, or is otherwise exposed to view at the surface. An *outcrop* is the part thus exposed. The parts of the strata exposed in the cuts on this page are outcrops.

Fig. 15.



177. *Dip* is the degree of inclination below a horizontal position. Rocks may dip but little, in which case they are nearly horizontal; or they may dip a great deal, or may even stand upright on their edges, when they are said to be *vertical.* They may also dip in any direction, *to the north* or *south, north-west* or *south-east.* The most prevalent dip in East Tennessee is *to the south-east.* In Fig. 15 the dip is in the direction *a p*, and in Fig. 16 in the direction *d, p*, as indicated by the arrows.

Fig. 16.



178. The *strike* is the direction of the line along which an outcropping layer cuts a level surface. It is horizontal, and at right angles with the dip. In Fig. 16 the direction of the edge *s t* is the strike of the layers represented. In Fig. 15 *s t*, parallel with the upper edge, is the strike of the rocks shown.

179. Folded and Inclined Rocks in Tennessee.—The rocks of West and Middle Tennessee, as before stated (p. 74), are mostly horizontal. Traveling in an easterly direction across the Cumberland Table-land, the strata continue horizontal, until a point about half-way across is reached, when indications of the folding of the rocks are met with. The strata begin to be inclined or to *dip;* soon a great and complete fold is encountered, and, as the eastern edge of the Table-land appears in sight, the western slope of another. Entering the Valley of East Tennessee, the evidences of folding become more marked. The *rocks very generally dip to the south-east,* and the edges of the strata are crossed in such succession as to show that the whole valley was once entirely filled with a series of complete or half-made folds, much crowded together. The folds, by a lateral pressure immensely great, were raised and *pushed over* toward the north-west, the Table-land acting as a resisting line or bulwark.

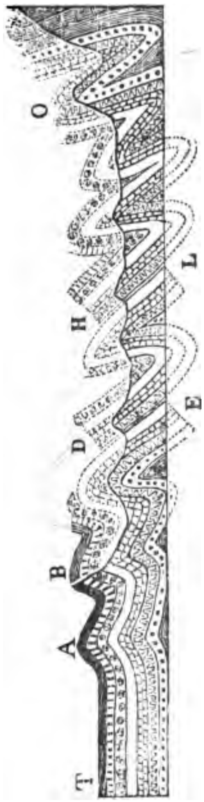
In the Unaka Range the folding and displacement of the rocks is even more marked than in the Valley.

180. Fig. 17 will illustrate what has been stated. It is a section, from the north-west to the south-east, across the Valley of East Tennessee, or rather a section across East Tennessee, as it includes the Unaka Range on the right, and the eastern part of the Cumberland Table-land on the left. The section is partly ideal and partly true to nature. Its object is to show how the strata have been wrinkled or folded in this part of the State. This it does, in a general way, satisfactorily. The form of the folds, the fact that they have been pushed over to the north-west against the Table-land, causing the strata for the most part to dip to the south-east, are, with other characters to be mentioned, illustrated by the cut. In

constructing it, however, many details have been left out, and some features exaggerated. The actual strata do not dip, as a general thing, so steeply, and some of the folds are less compressed.

It will be observed that the folds are divided, by a curving and wavy line which commences at B and terminates at U, into two parts—a light-shaded and a dark-shaded part. This line represents the *actual surface* of the Valley of East Tennessee, and of the slopes of the mountains on each side. The portions of the folds above this line have been *denuded*, or worn and washed away. They once filled what is now the Valley with mountain masses of rocks, but by vast erosion or wear, continued through a long time, and mainly by the agency of water, they have been removed and their strata worn down to the present surface. This explains why the edges of the strata outcrop on the surface.

Fig. 17.



Illustrative section across East Tennessee.

181. Displacements or Faults.—The rocks in their efforts, under pressure, to form folds, have not always succeeded in doing so. A series of strata would break, and one edge of the series would *slide over* the other, making one overlap the other, and producing a displacement of the rocks, called a *fault*. In some cases the strata have been much crushed, and the rocks thrown into complicated positions. In Fig. 17 the part between D and E shows a displacement, or fault. The edge D was once joined to E; but the group of strata was broken, and the edge D was pushed up and

over E. Between H and L is a similar displacement and fault.

The plane of separation between the overlapping part D and the overlapped part E is the place of the fault. This, on the actual surface of the country (the section of which is indicated in the figure by the wavy line, as stated), appears as a line running generally in the same direction with the outcropping edges of the strata. This direction, so far as Fig. 17 is concerned, is of course at right angles to the face of the page on which the figure is printed. When a geologist travels across such a line or fault, he at once observes that the proper sequence, or order in which the strata naturally follow each other, is interrupted. After passing the fault, the very series over which he has been traveling will begin again. Thus if he has traveled over the edges of strata, designated by *a*, *b*, *c*, *d*, and *e*, and then comes to a fault, he will, after passing it, meet perhaps with *b* again, and then with *c*, *d*, *e*, etc., in order as before. Indicating the fault by a vertical line the arrangement may be *a*, *b*, *c*, *d*, *e*, | *b*, *c*, *d*, *e*, or something similar, the series on each side of the fault being more or less complete.

182. There are many long *faults* in East Tennessee, along which two sets of strata, one of which was once, when the rocks were undisturbed and horizontal, hundreds, or it may be thousands of feet above the other, are brought right together. These faults extend, like the ridges and valleys, in a north-easterly and south-westerly direction.

183. It may be stated here that the order in which the strata of a denuded or decapitated fold are arranged is well illustrated in Figs. 13 and 14. Traveling across the edges exposed as at *b*, the order is 1, 2, 3: 3, 2, 1. In this case 3 was the lowest stratum and 1 the uppermost, before the folding took place, or when the rocks were horizontal. If a fold lies *below* the surface the order is reversed. Had the same strata been folded

downward, the order would have been 3, 2, 1 : 1, 2, 3, the uppermost stratum in this case being inside.

In the section, Fig. 11, on the same page, the strata rise in an anticlinal fold on the left, and sink in a synclinal one on the right. The order in which they outcrop at the surface is, commencing at the left end: VI, V, IV, III : III, IV, V, VI : VI, V, IV, III, II.

184. Study of the Strata; Begin at Home.—It is very desirable for students in geology to study these sections, the facts about the folds, the faults, and the order of outcropping strata until they are understood. It is especially important for students in East Tennessee. Without this knowledge they will never be able to comprehend the structure of the country they live in. The whole land is beautiful and grand in its rocky structure, as well as in the disposition of its mountains, hills, and dales, and it is unfortunate, that, for lack of knowledge, so many are, comparatively, blind to it all.

185. Let the student make practical work of it. *Begin right at home.* Let him make out the different strata that he has been playing, or hunting over; see whether limestone, sandstone, shale, or other rock; observe the color, structure, hardness, how thick they are, the order in which they occur, whether they contain shells, chert, or minerals; if containing shells, let him study these until he knows their forms, and can distinguish one from another. If living in East Tennessee, let him further notice the dips of the rocks, search for indications of a fold, or evidences of a fault.

By work of this sort, which any apt and zealous pupil of fifteen can carry out, the rocks of one's neighborhood, seen in the fields and hills and outcropping in the branches, will become known, and so known, as, like the faces of familiar friends, to be easily recognized when met with in other and distant places. Many a distinguished geologist, with but little assistance from books or teachers, commenced his career in this way.

186. (*b.*) THE UNSTRATIFIED FORM.—*Unstratified rocks* do not lie in layers or strata. As but few rocks having this form exist in Tennessee, we need not dwell here. On pages 66 and 67 the unstratified condition is mentioned as a characteristic of *granite.* The rocks of trap dikes (pp. 61, 69), like the Palisades on the Hudson, are also unstratified.

187. (*c.*) THE VEIN-FORM.—This, in the classification on page 71, is given as the third and last form in which rocks occur. *Veins* are made by the filling up of cracks or fissures in the rocks, the fillings being the veins. The fissures may have been very narrow, or many feet, or even rods, wide, the veins resulting being correspondingly thin or thick. They may have had also great depths. The materials filling the fissures may be quartz, calcite, or other minerals, often with the ores of metals.

In Fig. 18 two veins are represented, *a* and *b*. In Fig. 19 are two ir-

Fig 18.

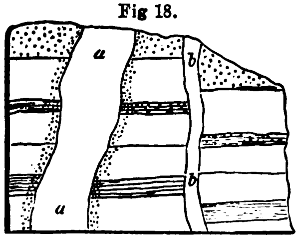
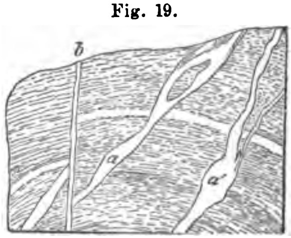


Fig. 19.



regular veins, *a* and *a′*. In this, moreover, is a third vein, *b*, which has been formed in a fissure made by the fracturing of the rocks after the formation of the vein *a*.

188. There are hundreds of thin veins intersecting the limestones rocks of Tennessee. The material composing them is generally crystalline and white *calcite.* Some of them consist, in addition of *fluor spar* (p. 47), *barite* (p. 198), and *lead and zinc ores* in small

quantities. In the rocks of the Unaka Range are also many veins, the material of which is often white *quartz.*

The noted copper veins of Ducktown will be spoken of in Part V.

The rock-material and ores of most veins have been brought into the fissures through the agency of water. Dikes are veins formed by the filling of the fissures with melted rock.

II.—Denudation.

189. Erosion and Removal of the Rocks.—The wearing and washing away, or, as geologists express it, the *denudation* (den′-u-da-tion) of strata, have been referred to on previous pages. The rocks show the effects of such wear and removal on a stupendous scale. By the folding and consequent upturnings of the strata, the rocks, in mountainous regions, often reached to elevations thousands of feet above the level at which we now find them. All this elevated matter has been worn away by the action of rain, frost, and ice, and carried back to the sea. Collapses and contractions of the earth's crust raised the strata, and water has cut them down, and *sculptured* them into the existing mountains and valleys.

190. Examples.—The elevation and subsequent denudation of the strata in East Tennessee have been explained on pages 80 and 81. There is good reason for believing that the strata, which outcrop around and beneath the city of Knoxville, once extended to elevations hundreds, or even thousands, of feet above the present surface. All that was above has

been removed, and the city stands on the outcropping edges of the remnants of strata.

The rocks, upon which Chattanooga and all the towns of the Valley of East Tennessee are built, are outcropping remnants, and have a similar history.

Horizontal rocks have also been subjected, in many regions, to great denudation. The gorges of the Colorado, spoken of on page 73, and, in Tennessee, the gulfs and coves of the western sides of the Cumberland Table-land, the whole of the Central Basin, the valleys of the rivers in Middle and West Tennessee, have been washed out of strata once continuous. The rocks exposed at Nashville had, at one time, a series of strata, certainly not less than a thousand feet in height, piled upon them, and the same is true of all the towns in the Basin.

191. Formation of Sequatchee Valley.—This valley, the surface features and relations of which are described on page 31, is a good example of denudation preceded by the folding of the rocks. Its structure is, as stated, much like the trough A in the cut on page 77. A fold was first formed, like B or C, and then the valley was excavated along its back.

The cut on the opposite page, Fig. 20, is a section of the formations and country extending, from a point about eight miles north of Jasper, in Marion county, in a south-easterly direction, to the eastern base of Lookout mountain, a distance not far from twenty miles. It begins at the point A on the *Cumberland Table-land*, and crosses, in succession, *Sequatchee Valley* (A to C), *Walden's Ridge*, (C to E), *Lookout Valley* (E to L), and *Lookout mountain* (L). The dotted lines represent the portions of the strata that have been denuded. The lines under B present a cross section of the strata of the great fold and mountain (originally much like B in Fig. 10, p. 77), the washing away of which, lengthwise along its summit, formed Sequatchee Valley. This fold was raised out of the very bosom of the Table-land, and to an elevation more than a thousand feet (at some points more than two thousand feet) above its top. It lay, like a straightened and half-buried monster serpent, lengthwise with the Table-land, extending in a south-easterly and north-westerly direction for 225 miles.

half in Tennessee and half in Alabama. The greater and southern part of the Tennessee half has been excavated, and is now Sequatchee Valley. The northern part, but partly denuded, is a broken range of mountains lying in a line with the valley, and between its head and Emery river in Morgan county. Crab Orchard mountain is one of this range.

Fig. 20.

This Sequatchee fold, as we may call it, is the "great and complete fold" referred to on page 80, and first encountered in crossing the Table-land from the west.

192. Valley-making and Ridge-making Rocks. Appalachian Geology.—We have seen how the rocks have been folded and elevated, and how then they have been denuded, or worn and washed, down to the valleys and mountains, as we now find them. In this wear and denudation, the softer and the more soluble strata, such as *soft shales* and *limestones*, have yielded more to the denuding agencies, and have worn deeper, than the harder strata, such as most *sandstones*, *roofing slates*, and *gneissoid* rocks. The soft strata have thus been removed, while the others, resisting the wear, have, to a great extent, remained. The excavation of the first has produced the valleys, and hence they may be called *valley-making* rocks; the others have been left, and form the ridges and mountains, and hence they are *ridge-* or *mountain-making*. The dis-

tinction is a good one, and will aid us in understanding the surface features, the *sculpturing* and topography of the country.

In Fig. 11 (p. 78), on the left-hand side, a denuded fold is represented, the strata of which are numbered II, III, IV, V, etc. No. III is soft, and has, by yielding to denudation, produced a valley. No. IV is a sandstone, separated into an upper and lower part by an interposed layer. This rock is hard, has not yielded like the others, and hence remains in high ridges on each side of the valley

193. We can now understand why it is that the valleys and ridges of East Tennessee, and in fact of the whole Appalachian belt from Maine to Alabama, about which we have said so much, run in parallel lines to the north-east and south-west. First, the rocks were raised in a succession of immense folds, lying in the characteristic direction; then they were worn and sculptured by denuding agencies, the soft strata of the folds yielding and forming valleys, the hard in good part remaining and making ridges and mountains. The outcrops of the strata, and hence of course the valleys and ridges, have the direction of the original folds.

194. Denudation of Horizontal Strata.—In the denudation of *horizontal* strata, hard rocks, as sandstones, have often resisted wear so as to form table-lands. The Cumberland Table-land owes its formation and preservation, as a table-land, to the hard sandstones which form its top or cap (p. 32). Without this *protecting* rock, the limestone strata which make the base of the mountain would have long since been removed. The outstanding cliff-edges of the Table-land are due to the weather- and water-resisting power of the rock.

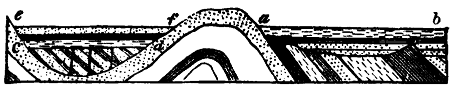
The outlines of the Central Basin are sharply defined by the hard, often flinty, edges of the rocks, which cap the Highland Rim. These edges, as well as the cliff-edges of the Table-land, are like the edge of a stiff crust overlying some softer material.

Hard layers very frequently give origin to ledges and terraces on the sides of hills. The ledges C and B in Fig. 8, page 73, have been formed by such layers.

195. Unconformable Strata.—It has often happened in the geological revolutions of the earth, that one set of strata has been folded or tilted, and that afterward the surface thus formed has been again submerged, and another set of strata deposited upon it. In such a case the strata of the two sets are said to be *unconformable.* They do not *conform* in position. Those of the first or lower set are tilted, while those of the second or upper are horizontal, and rest upon the edges of the first. The strata of the first are also plainly the older.

We may have, in this way, three or more sets unconformable to each other. In Fig. 21 there are three sets of unconformable strata. Those of the lower and older set are folded on the left side of the cut, and dipping

Fig. 21.



and denuded on the right; those of the second rest in a hollow of the first below the line *c d*; while those of the third set, lying on both sides of the fold, are horizontal, and rest upon the rocks of the other two. The horizontal strata in this cut may be of two different ages, that is, two sets instead of one, for the part under *e f* may have been deposited before, or after, the part under *a b*.

III.—Fossils.

196. Remains of Animals and Plants in the Rocks.—The rocks, especially limestones, sandstones, and shales, often contain, imbedded in them, shells, corals, bones, teeth, leaves, stems, and other remains or relics of

animals and plants. Some rocks are entirely made up of them.

Most of the rocks about Nashville, for example, are little else than *consolidated masses of shells and corals*—the remains of animals that formerly lived and flourished. The very dust of the streets "was once alive." The shells and corals are different in kind from those now met with in the seas of the world. Many of them have strange forms. Their home was the great ocean which, in past ages, covered Tennessee. This ocean teemed with living beings, and, as individuals were constantly dying, its bottom became covered deeply with accumulations of shells and coral-skeletons, whole or broken, and mixed with mud. The accumulations were in time consolidated, afterward raised out of the sea, and are now our limestone rocks. Such is the history of most, if not all, the limestones of the State.

197. What Fossils Are.—These relics of animals and plants, of whatever kind, are called *fossils* by geologists. The word *fossil* is from a Latin word, meaning *that which is dug up*, and as fossils are dug out of rocks, or obtained from crumbling rocks, the name is sufficiently appropriate. Fossils are often called *petrifactions*, and many of them are petrified. When a piece of wood or a shell has its matter *replaced* by flint, or any other substance different from wood or the original matter of the shell, it is *petrified*. Fossils, however, are often found which are but little changed.

198. The Use of Fossils.—Every formation has, to a great extent, its own kind or species of fossils. Most of those found in one do not occur in any other.

The species of fossils found in the rocks about Nashville are quite different from those found around McMinnville, for the reason that the two places are on very different formations. On the other hand, the fossils found at Lebanon are the same as those occurring at Shelbyville, the formation of the two places being the same.

In this is seen one of the important and practical uses to which these relics may be put. A person well acquainted with the fossils of any particular formation, can tell, at localities, it may be, very distant, whether the rocks he meets with belong to this formation or not. A geologist, traveling for the first time in a country, can often know, *simply from the shells in a layer of limestone,* that the rocks of the region belong to the Coal formation, and that beds of coal may be found; or, that they belong to some other formation, in which a search for coal would be useless. The fossils give the information. Further, by means of fossils the formations of Tennessee can be identified with formations in the State of New York, in Canada, or even in Europe. Were there no such means of easy identification, the strata extending from Tennessee to New York might often be followed or traced out; but to follow or trace out strata from Tennessee to Europe would be impossible.

199. The study of the fossils (a branch of science called *Paleontology* (pa-le-on-tol′-o-gy), a word meaning *the science of ancient life*) has supplied the means of uniting all the formations in one grand and continuous record or *history.* Indeed, without these remains Geology would lose very much of its interest and importance. Of this, however, we shall learn in the next Part.

200. The Animal Kingdom; Its Classes, etc.—To have any proper or practical knowledge of fossils, it is necessary for the student to know something definite about the characteristics and classification of animals and plants. Let us consider the animals first.

The various and countless species of animals that now live, or have lived, upon the earth, are first divided into two great groups, namely: The VERTEBRATES, or those having an internal backbone, or internal jointed skeleton; and the INVERTEBRATES, or those without a backbone. This division, though not very scientific, is a convenient one for geological purposes.

The *Vertebrates* constitute a *sub-kingdom* by themselves; the *Invertebrates* are divided into *four sub-kingdoms.* Thus there are *five* sub-kingdoms in all, and these are still further divided and sub-divided. On the next page a table of the leading divisions, with brief descriptions and examples, is given. The table begins with animals of the simplest or lowest organization, like the *Sponges,* and ends with those of the highest grade, of which the *Quadrupeds* and *Man,* the highest of all, are examples. This order places the *Invertebrates* first; it is the most natural, and corresponds nearly with the order in which the animals, as represented by their fossil remains, occur in the formations, and the order also in which the species appear to have been created. The first and lowest of the formations contain the remains of invertebrates only. Ascending through the series we soon meet with the remains of *Fishes,* the lowest class, and the first of *Vertebrates* to appear; and then in succession with *Reptiles, Birds,* and *Mammals.* Of the Mammals, the Quadrupeds belong to the latest and uppermost formations. Man's place is at the very top.

A. Invertebrates.

1. **Sub-kingdom. Protozoans.**—This name means *first animals.* They are first in simplicity of structure, and may have been the first created. Bodies of jelly-like consistence, generally minute, with no organs, unless a sort of stomach. The *Sponges,* which are aggregations of hundreds of minute individuals, and a group of animals called *Rhizopods,* are examples. (See next page.)

2. **Sub-kingdom. Radiates.**—Animals having a radiated structure, that is, having their parts arranged as if around a centre. They have a central or nearly central mouth. In form, they may be globular, cucumber-shaped, cake-like, umbrella-shaped, and star- or flower-shaped. A few live in fresh water, but the great mass in the sea. The forms of some of them are given in Fig. 22 on page 95, and the principal kinds described.

3. **Sub-kingdom. Mollusks.**—Animals having *soft bodies* which are generally protected by an outside shell, as *Snails, Periwinkles, Muscles, Clams, Oysters,* and *Cuttle-fish.* The last have an internal bone or shell. The word *mollusk* is from the Latin *molluscus,* meaning *soft.* On page 97, Fig. 24, is a group of them.

4. **Sub-kingdom. Articulates.**—Animals with the skin more or less hardened into a *crust,* which is divided across into rings or segments jointed together and forms an *outside* skeleton. The *Insects, Centipedes* ("hundred-legged worms"), *Spiders, Lobsters, Crawfish,* and *Worms,* belong here. The forms of some of them are shown in Fig. 25 on page 99.

B. Vertebrates.

5. **Sub-kingdom. Vertebrates.**—Back-boned, and many of them familiar animals. There are four classes, as follows:

   (*a.*) Fishes.—Animals breathing by means of *gills.* The following are divisions: *Common fishes* like the *Perch, Trout, Salmon; Ganoids,* as the *Sturgeon,* and *Gar-pike;* and *Selachians,* including the *Sharks* and *Rays.* See pages 99–101.

   (*b.*) Reptiles.—Cold-blooded, with a covering of scales or a naked skin. *Alligators, Lizards, Turtles, Snakes,* and *Frogs.*

   (*c.*) Birds.—Well known animals with a covering of feathers.

   (*d.*) Mammals.—Animals that suckle their young, and have a skin provided with hair on the whole or some part of the body, as the *Dog, Horse,* and *all Quadrupeds, Seals, Whales,* etc. *Man is* included here

201. Notes and Illustrations. Protozoans.—A *Sponge* is usually a colony of numerous, minute animals, supported in a mass by a skeleton or framework of horny fibres, or of needles which may be calcareous or flinty. The common *Sponges*, so called, used for rubbing out marks, cleaning slates, and for washing purposes, are examples of frameworks consisting of horny fibres. All the kinds are found fossil in the rocks.

Rhizopods (rhiz′-o-pods) were inclosed in shells (consisting of one or more *minute cells*), and these, though generally not larger than grains of sand, were so abundant as to form the greater part of some rocks. Chalk is largely made up of them. *Rhizopod* means *root-footed.* Some of these animals extended out fibre-like or thread-like arms through pores in their shells; hence the name.

202. Radiates.—In this sub-kingdom are included *Polyps*, the *coral-making* animals; *Jelly fishes*, called *acalephs* (ac′-a-lephs); *Star-fishes; Crinoids*, or the *Stone-lilies;* and *Sea-urchins*, called *Echinoids* (ech′-i-noids). The Radiates are of great importance to the geologist. Nearly all have *hard* parts, either an inside unjointed skeleton called *coral*, or a sort of hollow shell or box, made up of stony pieces, and covered with a sort of skin. Most of the kinds are abundant in the seas of the present day. Multitudes lived in former times, and their remains fill many of the rocks.

203. In the group on the next page (Fig. 22), 7, 8, and 9 are pieces of polyp-masses. The flower-like ends are the living polyps, each with a circle of tentacles around the margin, and a mouth in the centre. When the animals die, the stony coral, which supported them, remains, and is often a beautiful structure.

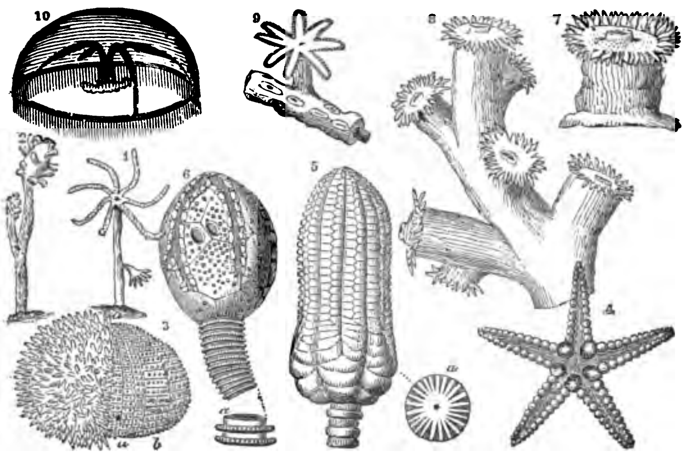
At the upper left-hand corner, 10 is an umbrella-shaped *Jelly-fish*, or *Acaleph.* Below this, 1 and 2 are other Acalephs, resembling polyps. Some of the kinds form corals.

At 4, in the lower right-hand corner, is seen a *Star-fish*, an animal related to the crinoids next described, but having no *stem.*

204. Nos. 5 and 6 are *Crinoids* (cri′-noids), or Stone-lilies. *Crinoid* means *lily-like.* These animals have been compared to flowers, either with the petals expanded, star-like, or closed in the bud. They are fixed to the bottom of the sea by a stem which makes them all the more like flowers. It is only, however, in their forms that they happen to be something like

flowers; in structure they are altogether different. The crinoids consist of a hollow body or box, made up of stony pieces, which contains the digestive organs. The mouth is at the upper part of the box. Many of them have arms, also made of pieces, which they can spread out or close up, as a flower does its petals. In 5, the arms are closed up. No. 6 is a crinoid which had no arms. It shows the body and a part of the stem. The stems by which they are supported, and at the same time attached to the bottom, are often a foot or more in length, and can be bent, like a backbone, in any direction at will. They are made up of stony buttons

Fig. 22.



A Group of Radiates.

piled one upon another, and held together by small muscles. In 5, *a* is one of the buttons magnified; in 6, *a* represents two of the buttons of this specimen. When the animal dies the stems often fall to pieces, the buttons becoming separate.

On pages 144 and 154 other species of crinoids are figured.

205. Crinoids were once very abundant in the ancient seas; there are but few of them now living. Many of the rocks of Tennessee contain their remains. The buttons of the stems, especially, are very common. Some limestones are in great part, or wholly, made up of them.

hence they are known as *crinoidal limestones.* Fig. 23 represents a piece of such limestone. It is seen to be made up of broken stems, and separate buttons of different sizes. The buttons vary in size from that of a nickel down to little disks, which, when put together, would form a stem no larger than a knitting needle.

206. In Fig. 22, on the last page, 3 is one of the forms of a *Sea-urchin.* Its outer part is a hollow box made up of pieces and covered with spines. In the cut the spines on one side are removed to show the box. The mouth of this animal was below, at or near the centre.

Fig. 23.

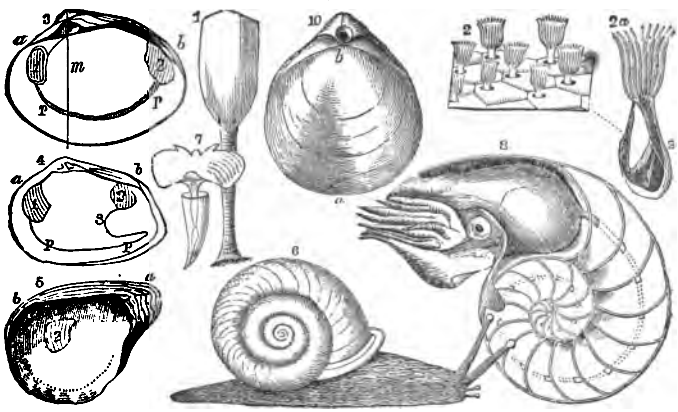
207. Mollusks.—The Mollusks included the following divisions:

(*a.*) *Those having arms around the head,* and possessing large eyes. They are called *Cephalopods* (ceph′-a-lo-pods), a term derived from two Greek words meaning *head* and *foot.* In the group on the opposite page (Fig. 24), 8 is one of them, the *Nautilus,* and a living species. The animal is seen occupying the large end of a coiled shell, which has had one side removed to show the interior. It will be seen further that the shell is *divided into chambers* by cross-partitions. Most of the extinct Cephalopods had chambered shells, which are often found fossil. The shells were not always coiled; some were but slightly curved; many even straight. The latter belong to the genus *Orthoceras* (or-thoc′-e-ras), a word meaning *straight horn.* In the group (Fig. 32), on page 133, 6 is an Orthoceras. They varied in length from an inch or two to six or more feet. The shells of the Cephalopods had a tube, called the *siphuncle,* running through the chambers; that of the Nautilus is indicated in 8. All of the Ceph-

alopods having external chambered shells, with the single exception of the Nantilus, are extinct.

208. (*b.*) *Mollusks*, like the Snail, *having a head, but no arms*, and generally carrying a spiral shell. Many of them are called *Gasteropods* (gas′-ter-o-pods), from the fact that they make a sort of foot of the under side of the body. The common *Snail*, (6, in Fig. 24), *Periwinkles* from the rivers, and *Sea-snails*, which supply many beautiful and large shells, are examples. Others are called *Pteropods* (pronounced ter′-o-pods), a word meaning *wing-footed*, for the reason that they have a pair of wings for swimming. No. 7, in the group below, is one of them.

Fig. 24.



A Group of Mollusks.

209. (*c.*) *Mollusks without heads*, called *Acephals* (ac′-e-phals). *Acephal* means *headless*. The *Muscles, Clams, and Oysters* belong here. The shell of one of these animals consists of two pieces, or valves, applied respectively to the right and left *sides* of the body. In Fig. 24, 3, 4, and 5 are valves of Acephals. The margin *a* of each valve is the front, the mouth facing this; the margin *b* is the back. No. 5 is the valve of an oyster.

210. (*d.*) This division includes a group of marine Mollusks, each of which has *a shell in two pieces*, like the Acephals, but the pieces *are not right and left*, and applied to the sides of the animal; they are

rather *top* and *bottom*, one being applied to the *back* and the other to the *ventral surface*. They are known as *Brachiopods* (brach′-i-o-pods), meaning *arm-feet*, the name referring to the fact that the animal has two spiral arms within. Generally the valves in Acephals are *vertical* when in position, and alike in form and size, excepting that one is right and the other left. They are symmetrical like the lids of a book. The valves of Brachiopods are unlike in form and size; are horizontal, like a chest and its lid, and are unsymmetrical.

No. 9, in Fig. 24, is a Brachiopod. The larger valve (the ventral) has a beak with a hole in it, through which a cord passes, by which the animal is attached to a rock, or some support. No. 1 is another, a species of the genus *Lingula*, the long cord of which is shown.

The fossil shells of Brachiopods are very abundant in the older formations. Very few Mollusks of this kind are living now.

211. (*e.*) The last group of Mollusks includes *the Bryozoans* (bry-o-zo′-ans). The word means *moss-animals*. They are of minute size, and pack their little shells together in thin layers, lace-like or branching forms. The layers often incrust larger shells, the hard parts of other animals, stones, etc. Some of the more delicate kinds resemble moss, and hence the name. Their aggregations of shells may be called corals, and the animals themselves look like polyps. In Fig. 24, 2 is a magnified representation of some of them standing out of their cells. On the right 2*a* is a section of one still more magnified.

212. Articulates.—These animals are divided into *Land Articulates*, including *Insects*, *Spiders*, and *Centipedes*; and *Water Articulates*, as *Crabs*, *Lobsters*, *Crawfish*, *Worms*, etc. Of the water kinds, 5 and 6 (Fig. 25) are representations (magnified six times) of the female and male of a species having feet or legs comparatively defective.

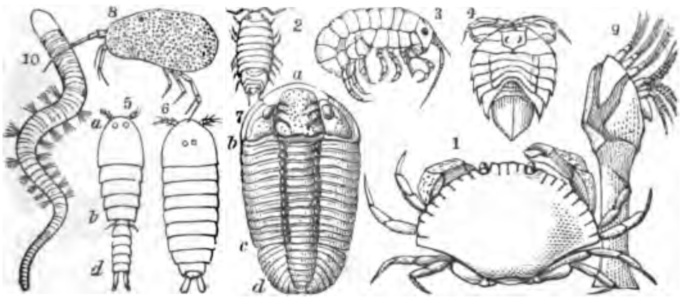
213. Near the middle of the group, 7 is a *Trilobite* (tri′-lo-bite), resembling in some respects 2 and 4. *Trilobites* are only known by their fossil remains, as none are now living. They form an order of Articulates of great importance to geologists. The word *trilobite* (*tri-lobed*) refers to the division of the back of the animal into three lobes or ridges, more or less distinct. They appear to have had no legs or paddles; or, if these existed, they were soft or fleshy, and not of a character to be preserved as fossils. They were of all lengths, from half-an-inch, or less, to twelve

inches. In the Trilobite represented, the end *a* is the *head piece*, the end *d* the *tail piece*, and the middle part *b c* the *body*, which was divided into movable segments. Some of the Trilobites had the power of doubling themselves up. On page 122 is a good figure of another species; and, in the groups on pages 127 and 132 other species are represented.

214. Nos. 2, 3, and 4 (Fig 25) are bug-like Water Articulates. No. 4 has the form of a Trilobite.

The animal represented at 8 belongs to a group of Articulates called *Ostracoids.* They are inclosed in a two-valved shell, like the *Oyster*, and hence the name. But the shell is thin, and otherwise quite different from that of the oyster. Many of them are minute animals, and swarm in some waters. Fossil Ostracoids, looking like good-sized black beans, are

Fig. 25.



A Group of Articulates.

common in the rocks of Shelbyville, Lebanon, the lower parts of Columbia, and of other points where the same strata are exposed.

No. 9 of the group is a *Barnacle*, an *Articulate* which attaches itself to rocks, wood, ship-bottoms, etc., by a fleshy stem. No. 1 represents a *Crab.* On the left of the group, 10 is a marine worm, known as the *Lob-worm.*

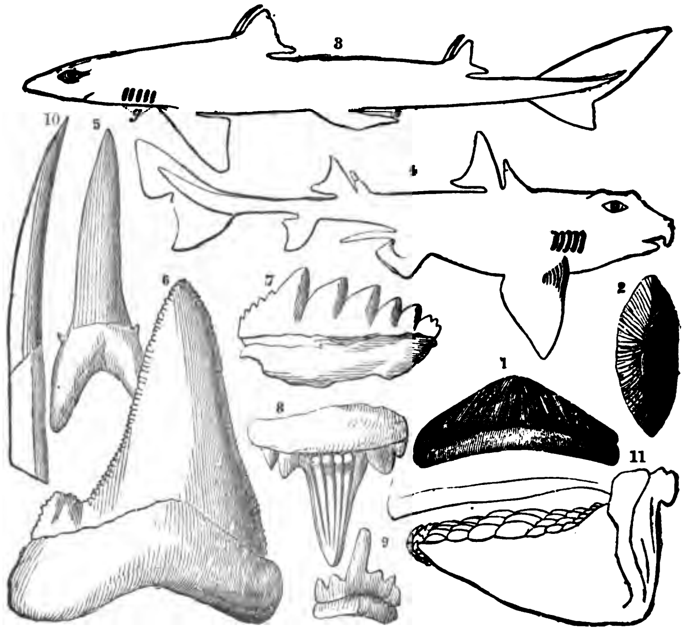
215. Vertebrates.—The classes of this sub-kingdom have been given in the table on page 93. We will add only a few paragraphs and cuts with reference to the *Selachians* and *Ganoids* among the Fishes.

216. The *Selachians*, including, as stated, the *Sharks* and *Rays*, have a skin covered with hard, bony, and rough points. Their skeletons are

in good part, cartilage in place of bone. The term *selachian* is from the Greek for *cartilage*.

In the group of cuts, Fig. 26, 3 and 4 are outlines of sharks. The two differ in the position of the mouth, and also in the arrangement of the teeth. In the former, the teeth are in pavements on the jaws. No. 11 shows them on the lower jaw.

Fig. 26.



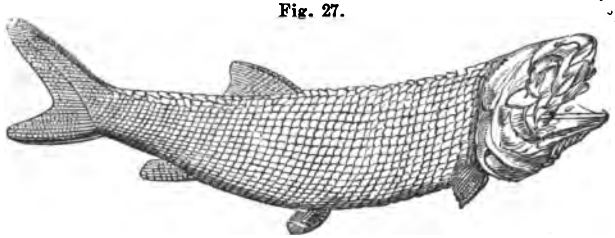
Sharks and Sharks' Teeth.

All the remaining forms of Fig. 26 are illustrations of different kinds of Sharks' teeth. These fishes were created, with the Ganoids, at an early date. Their teeth are often found fossil.

217. The *Ganoids* (ga′-noids) are represented, comparatively, by but few living species. The order is an ancient one. Fig. 27 is one of these fishes as found in the rocks. The tail in the oldest division of Ganoids is *vertebrated*, that is, the backbone, or cartilaginous part representing it, extends out to the extremity of the tail, generally to the point of the upper lobe,

as in the figure, but sometimes to the point between the lobes. In more modern Ganoids, as well as in common fishes, the backbone stops at the root, or commencement, of the tail. Ganoids were covered, like Gar-pikes, with thick, bony, and shining scales, or rather plates, quite different from the thin, flexible scales of common fishes. The *shining* plates have given name to the order, the term *ganoid* coming from a Greek word which means *shining*.

Fig. 27.



A Ganoid of the Genus Palæoniscus.

218. The Plant-kingdom.— The plants of the earth, including both living and fossil forms, are divided into two great groups, namely:

(*a.*) *Flowerless Plants*, or *Cryptogams* (cryp′-to-gams), as *Ferns*, *Sea-weeds*, *Mosses*. They have no proper flowers, nor true seeds, there being in the place of the latter simple *cells*, which botanists call *spores*. (*Seeds* contain an *embryo plant* with a store of nutriment in some form to support it.)

(*b.*) *Flowering plants*, or *Phenogams* (phen′-o-gams), as most of the common plants, *Oaks*, *Pines*, all our forest and fruit trees, most weeds, *Grasses*, garden herbs and shrubs. They have distinct flowers and true seeds.

219. The Flowerless Plants are sub-divided into three *classes*, and the Flowering into two, making five in all, as follows:

A. Flowerless Plants.

1. *Thallogens* (thal′-lo-gens); *Bed- or Mass-growers*. Humble plants of lowest organization; made up wholly of cellular (pithy) tissue, which may be soft or compact and hard, watery, or dry and crusty; growing, without any distinction of stem, leaf, or root, in flat expansions, layers, strings, branching tubes, ribbon-forms, masses of symmetrical or irregular shape, or in single cells. *Sea-weeds*, *Lichens*, and *Fungi* (pronounced fun′-ji),

are *Thallogens.* The Fungi include *Mushrooms, Toadstools, Puff-balls*, the minute plants which form *Mold, Mildew, Smut*, and *Rust*. The dry, crusty expansions that grow on rails, logs, and rocks, are *Lichens* (lich′-ens).

2. *Anogens*, or *Top-growers.* Wholly of cellular tissue, like the last, but growing up in *leafy-stems.* The *Mosses* belong here.

3. *Acrogens*, also *Top-growers*, the words *anogen* (an′-o-gen) and *acrogen* (ac′-ro-gen) having the same meaning. These are plants containing woody tissue and tubes or ducts, such as are found in plants of higher grade. Among them are *Ferns, Lycopods*, or *Ground-Pines*, and Equiseta (ĕq-ui-se-ta), the latter known as *Horse-tails* and *Scouring-rushes.* Species of all these divisions, some of them large trees, occur in the rocks as fossils, especially in the strata of the coal formation.

B. Flowering Plants.

4. *Endogens* (en′-do-gens) or *Inside-growers.* The class includes the *Palms, Cane, Rattan, Grasses, Indian Corn, Lily.* The plants have no proper bark; the wood of such as are trees or shrubs does not grow by the successive addition of new layers to the outside; hence the end of a Palm log or Rattan stick shows no rings of growth.

Remains of Palms occur in the later formations, and are numerous now. They may be regarded as modern plants.

5. *Exogens* (ex′-o-gens), or *Outside-growers.* Including *Oaks, Maples, Apple, Pines, Spruce*, and all our forest and fruit trees, and most shrubs and herbs. They have a bark, and show rings of growth.

There are two orders of Exogens. The *first* embraces the *Gymnosperms* (gym′-no-sperms), or *Naked-seeded Plants*, the seeds lying naked at the base of the scales of cones. The *Pines, Spruces, Hemlocks*, etc., called *Conifers* (con′-i-fers), or *Cone-bearing* trees belong to this order. The *Cycads* also are included. These are trees usually with short trunks, having the appearance of Palms, uncoiling their leaves after the manner of Ferns, but yet in their wood and cone-fruits like the Pines.

There are but few Cycads living. In the age following the coal period they were abundant, and the characteristic trees of the forests. The Conifers appeared long before the Coal age, and have constituted an important part of all succeeding forests up to the present day.

The *second* embraces the *Angiosperms* (an′-gi-o-sperms, or *Covered-seeded*

Plants. The seeds are inclosed in seed vessels. All the Exogens, except the Conifers and Cycads, are included in this division.

The Angiosperms, as Magnolias, Willows, Walnuts, Maples, Oaks, Poplars, etc., first appeared, with the Palms, in the later formations.

IV.—The Geological Theory of the Earth.

220. The Fiery Earth.—The earth was once a ball of fire, like the sun and the fixed stars—a globe of melted, liquid rock. As a consequence, it has ever been a cooling body. This, at least, is the theory of geologists, and they have good reasons for entertaining it. Even now an auger could not anywhere penetrate its comparatively cooled exterior a few thousand feet without reaching heated rocks.

221. The water from the deepest Artesian wells—wells made by boring, and from which the water flows spontaneously like a fountain—is too warm for ordinary drinking. The deepest mines have a high temperature. The multitude of volcanoes; the melted rock ejected through fissures; and the formation of dikes (pp. 61, 69); earthquakes; the phenomena of hot springs; the metamorphism of rocks (p. 61); the folding and crumpling of strata (p. 76)—all point to the probable existence, at the present time, of fire-seas below, as well as to the liquid and fused condition of the entire earth in the unmeasured past.

222. The Crust.—The original liquid globe, by slow cooling through very long time, began finally to form a crust. This was at first thin and fragile, and easily broken up by the fiery billows. It formed again, was broken and reformed, again and again. At length, as the cooling proceeded, the crust became

more stable, and the *first rocks* were made. These were crystalline and unstratified; perhaps chiefly granite.

223. In the meantime the surface cooled enough to permit the watery vapors, hitherto, in some form, a part of the atmospheric envelop, to condense and cover the earth. Thus the *ocean* appeared, which at once began the work of making *stratified rocks*. The waters, still hot, by wearing and denuding the first rocks, strewed the sand or mud resulting over the submerged exterior, covering and concealing the worn surfaces of the first granites, or whatever they were, with stratified layers.

224. Thus was the first set of strata formed, and, having been deposited and consolidated in hot waters, they were doubtless crystalline. And these in turn, worn and washed by the waves, supplied new sand and mud for new layers, beneath which they too were more or less buried. And this continued until thousands of feet of strata were in some places piled up.

225. Land and Life.—While this was going on, the continents and the ocean beds began to be outlined; limited areas of the rocks rose above the waters, and the dry land appeared; the heat was diminished, and plants, soon to be followed by animals, were seen—the first introduction of life by the great Creator. This marks an epoch—a distinct day. Now began the making of the fossiliferous or fossil-bearing rocks, which continued through long ages.

226. The Sequel.—As the sequel to what has been said, let the reader add the account of the "Origin of Tennessee Rocks" (p. 59), the starting point of which dates from this time; also, and more especially, the paragraphs on pages 76 and 77 bearing on the *position*, *folding*, and *ele-*

vation of the strata, as well as the paragraphs under Denudation, commencing on page 85, which treat of the *erosion* and *wear* of strata, and of the *sculpturing* they have undergone in the production of the present surface.

227. The Central Mass of the Globe not Liquid.—We have spoken of the cooling of a liquid globe, and the formation of a solid crust at its exterior. It must not be inferred from this that we believe the whole interior to be now in a melted, liquid state. It is probable, indeed, on account of the immense pressure existing, that solidification began first at the centre.

The great mass of the earth within may be solid, though more or less heated. If so, then between this inner solid part and the crust lie great fire-seas, or lakes of melted rock.

228. Thickness of the Crust.—The thickness of the crust of the globe is not known. The estimates vary from 40 to 100 miles. In boring Artesian wells (p. 103) the temperature of the rocks (after passing the limit to which the heat and cold of the seasons penetrate) increases at the rate of about 1° for every 50 or 60 feet of descent. At a depth of about 8,000 feet, the rate of 1° for 50 feet would give heat enough to boil water, and at 28 miles heat sufficient to melt iron. But pressure has much to do with the melting of substances. A temperature sufficient to melt iron or rock at the surface would fail to do so at a considerable depth ir the earth.

PART IV.

THE FORMATIONS.

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229. In the last Part we studied the composition, kind, and origin of the rocks; what the strata are, and how they are disposed in the hills and beneath the valleys. We studied also the fossils they contain, relics of plants and animals that lived, generation after generation, in ages gone by.

Having this information, we are prepared to consider the *great formations* in which the strata are naturally grouped. And as each formation includes the strata deposited in an age, and as, like the ages, they follow in succession, this part of the work becomes a *history*. (See latter part of paragraph 68, page 41.)

230. We shall first consider the classification of the formations, especially of those represented in Tennessee; then, taking up each in succession, observe the areas of the State within which they outcrop, learn their divisions, kinds of strata, and the characteristics of their fossils. To this will be added lists of the minerals and useful rocks occurring in each, the proper descriptions of which are reserved for Part V.

What is understood by *formation* has been sufficiently explained in connection with the meaning of *stratum*, on page 4. See also page 72. The student is expected to review what is said on those pages with reference both to formation and stratum, and to be able to define them, and to state how they differ.

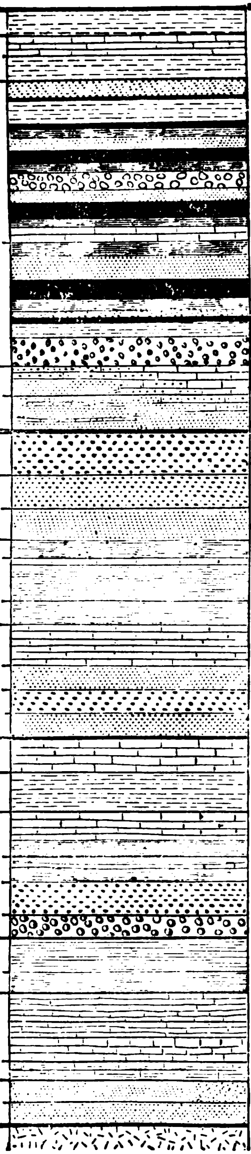
CHAPTER X.

Classification of the Formations.

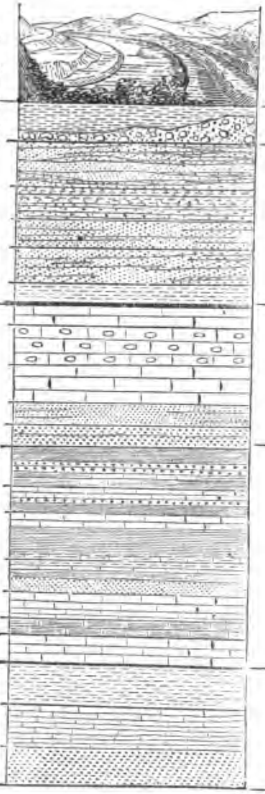
231. Ages and Periods—the Great Formations and their Sub-divisions.—Reference has been made several times to ages, but we must be more explicit. Past time is divided into cycles, called *ages,* all of very great, but not of equal, length. During each age a *great formation* was made, there being as many formations as ages. One of the cycles is, for example, the *Silurian age,* and, during its long lapse of years, a vast pile of strata was built up, which has been named the *Silurian formation.*

232. All the ages of past time, commencing with the origin of the earth's crust and the first appearance of rocks, and extending down to the present day, are divided, with the exception of the *first,* into three or more *periods.* Each of these periods has its corresponding *minor* formation. We have, for example, among the Silurian periods, of which there are seven in number, a *Nashville period,* and a corresponding *Nashville formation,* the first being the time, during which the series of strata was deposited; the second, the name of the series itself.

233. The Section of Formations.—In the sections, or rather in the two parts of a section, on the next two pages, are represented (commencing at the bottom of the page, with the lowest and oldest, and ascending in order to the uppermost,) the formations of the globe with their



T.	Ages.		American Periods.	Tennessee Divisions.
PALEOZOIC TIME.	Carboniferous Age, or Age of Coal Plants.		15 Permian.	....
			14 Carboniferous, or Coal Measures.	(c) Upper Coal Measure. (b) Conglom'r'te (a) Lower Coal Measure.
			13 Subcarboniferous.	(c) Mt Limest'e. (b) Coral or St. Louis Lim'st'e (a) Barren Gr.
	Devonian Age, or Age of Fishes.		12 Catskill.	....
			11 Chemung.	....
			10 Hamilton.	Black Shale.
			9 Corniferous.	........................?
			8 Oriskany.	....
	Silurian Age, or Age of Invertebrates.	Upper.	7 Helderberg.	Linden.
			6 Salina.	....
			5 Niagara.	(c) Clifton. (b) Dyestone Gr. (a) Clinch Sandstone.
		Lower.	4 Trenton.	(b) Nashville. (a) Lebanon.
			3 Canadian.	(b) Lenoir. (a) Knox Group
			2 Primordial.	(b) Chilhowee S. (a) Ocoee Group
Archæan Time.			1 Archæan.	........................?



Times.	Ages.	American Periods.	Tennessee Divisions.
CENOZOIC TIME.	Age of Man, or Quarternary Age.	Recent.	(c) Alluvium.
		Champlain.	(b) Bluff Loam.
		Glacial.	(a) Orange Sand.
	Mammalian Age, or Age of Mammals.	Pliocene.	
		Miocene.	(b) La Grange Sand.
		Alabama.	
		Lignitic.	(a) Flatwoods Sand, etc.
MESOZOIC TIME.	Reptilian Age, or Age of Reptiles.	Cretaceous.	(c) Ripley.
			(b) Rotten Limestone.
			(a) Coffee Sand.
		Jurassic.	....
		Triassic.	....

corresponding ages, periods, etc. (Each formation, it will be recollected, and its corresponding age or period, have the same name.) It would be better if the two parts referred to could have been so arranged as to make a single unbroken column on one page. But this was not practicable. The student must suppose the one on this page to be placed immediately on the other, the word *Triassic* coming just above *Permian*, and the shaded part and vertical lines of both being continuous. The shaded part represents the different strata.

In this section (for the two parts make a single section) the student

can at once see the names, the number, and order of succession of the ages and periods, and of their corresponding formations.

234. On the left of the section the ages are grouped into grand divisions called *Times*. The first, the *Archæan* time, embraces but one age; the second, the *Paleozoic* time, three ages; the third, the *Mesozoic*, one and the fourth, the *Cenozoic*, two ages.

The word *Paleozoic* is from the Greek, and means *ancient life*, hence *Paleozoic time* signifies *Time of ancient life*. In the same way *Mesozoic time* signifies *Time of middle life; and Cenozoic time, Time of recent life.*

235. Those of the formations or divisions occurring in Tennessee are indicated in the right hand column. If a formation is found in this State its name is given; if not, its absence is indicated by the dotted lines. In some cases Tennessee names have been preferred, as, for example, *Nashville* in the place of *Trenton*.

236. Geologists have recognized *seven* ages (and as many corresponding great formations), the names of which are given in the section. The leading characteristics of the ages and of their formations and rocks are added below. The most important are dwelt upon briefly, as they will receive due consideration hereafter.

237. (1.) **Archæan Age.**—The *beginning* age; *Archæan* comes from the Greek for *beginning*. During this era the Archæan rocks were made—the first rocks of the earth's crust. So far as they can be seen, which is only in limited areas, as all that is Archæan is for the most part buried beneath later formations, these rocks are principally granite, syenyte, gneiss, mica, and hornblende schists, slates and granular limestone, with hard conglomerates and sandstones. The granites and syenytes are unstratified. The others, which are the rocks mostly to be seen, occur in strata, and

these are generally inclined, and more or less folded, giving evidences of the disturbance to which they have been subjected. There was no life in this age excepting perhaps near its close.

238. The principal outcrop of these rocks, in North America, is found in Canada and the northern part of the continent. They form there a great tract of surface, having the shape of a bent arm, the elbow resting on Lake Superior, and the arm embracing the region of Hudson's bay. This was the first land of North America, and a *nucleus* to which the other portions of the continent, in after ages, were added in succession.

239. Archæan rocks do not appear at the surface in Tennessee, unless the rocks of one or two small patches, on the North Carolina line, are of this age. One of these is the region of the "Bluff" in Cocke county, where the newly-named rock, *unakyte,* is found associated with protogine. (See pp. 67, 68.) The Archæan age of these rocks is yet doubtful. They may still be considered as belonging to the succeeding age.

240. (2.) **Silurian Age, or Age of Invertebrates.**— An era when shell-making Mollusks and coral-making Radiates, with Crinoids and Trilobites, flourished in the oceans. The animals were almost wholly Invertebrates. Toward the last Fishes began to exist. Salt waters covered the continents, with the exception of the limited Archæan tracts.

241. The rocks made during this era are conglomerates, sandstones, shales, limestones, and dolomites. In some sections these have been changed into metamorphic rocks (p. 61), and are now quartzites, gnessoid

rocks of different kinds, schists, slates, etc. Several strips of Silurian metamorphic rocks are found in the mountains bordering North Carolina.

242. The strata of the age are divided into two grand divisions, which are known as the *Lower Silurian* and the *Upper Silurian* formations. The latter we shall find to be the most important group of strata entering into the geological structure of Tennessee.

243. (3.) **Devonian Age, or Age of Fishes.**—This is a portion of time succeeding the last, and much like it in many respects. The Invertebrates still flourished, but Fishes were the masters of the seas. There was more land, and this began to be covered with plants and trees.

244. The rocks are about the same as those of the last age. In New York, Pennsylvania, and other states, they make a great series of strata, but in Kentucky, Tennesse, and Alabama, the strata are few and thin. In Tennessee the series, so great at other points, is represented by a single stratum, known as the *Black Shale*, rarely over 100 feet in thickness.

245. (4.) **Carboniferous Age, or Age of Coal-Plants.** This was an era of extensive lands, often submerged, upon which grew successive forests of trees, and smaller plants—Ferns, Lycopods, Equiseta, and Conifers (p. 102). These, in decaying, formed beds of vegetable matter, which ultimately changed to coal. To the kind of animals already mentioned as living in previous ages, were added Frog-like and other inferior Reptiles.

246. The strata formed were limestones, conglomerates, sandstones, and shales, with the addition of beds of coal. In Tennessee the rocks of the Cumberland Table-land, and also of the Highland Rim, belong to this age. The formation is an important one, and will receive attention in the proper place.

247. (5.) **Reptilian Age, or Age of Reptiles.**—This age is remarkable for the number, variety, and size of the Reptiles that lived during its continuance. Never before, nor since, has there been such a display of Reptile life. The plants called Cycads (p. 102), as well as Conifers, abounded in the forests of this reptile time.

248. The strata originating in the era are sandstones, limestones, etc., like those of the previous ages, but often less hardened.

The *Green Sand* or Shell Marl of McNairy and Henderson counties, in West Tennessee, and the "*Rotten Limestone*" of Mississippi and Alabama, are representatives of this portion of past time.

249. (6.) **Mammalian Age, or Age of Mammals, or the Tertiary Age.**—Here follows an era during which the Reptiles wane, and Mammals, numerous and varied, many of extraordinary size, some fierce and destructive, become the lords of creation. There were Horses, Tapirs, Deer, Camels, Squirrels, Rhinoceroses, Elephants, Mastodons, Wolves, Tigers, Panthers, strange animals called Titanotheres, Dinotheres, and Dinoceres, etc., all of which, though in most cases related to our living animals, or belonging to the same tribes, are extinct or lost species, and only known to us through their fossil skeletons and bones.

250. The continents were more than ever out of the sea. They put on a new and modern appearance; the animals remind us of living forms; the forests had none of the odd trees characteristic of the coal era; they contained Oaks, Poplars, Maples, Hickories, Dogwoods, Sycamores' Willows, etc., which, though not of the species existing, yet were so much like them as to give the forest a familiar aspect.

251. The rocks formed in the era are to be seen around the borders of the continents or in basins once occupied by Tertiary waters. They are the ordinary sandstones, limestones, shales, etc., though often unconsolidated, and merely stratified beds of sand, clay, or calcareous mud.

252. Most of the strata of West Tennessee are products of this age. The northern extension of the Gulf of Mexico, referred to in paragraph 119 (pp. 59, 60), was the arm of the ocean in both Reptilian and Mammalian time. From these waters the sands and clays were deposited.

253. (7.) **Age of Man, or Quarternary Age.**—In this Man appears—the crowning work of creation.

In the *first* part or *first* period of this age, the northern portions of the continents, *more elevated than now*, were covered with wide-spreading and slowly-moving streams of ice, called *glaciers* (pronounced gla′-seers), which scoured out valleys and shaped the surface.

254. In the *second* period of the age the same lands *were brought down to a low level;* the glaciers melted away and left much of the surface strewed with the gravel and sand formed by the ice; and the valleys were further filled with alluvial beds.

255. The gravel and sand thus formed are known in geology as the *Drift.* This still covers large areas of the states north of the Ohio river. South of the Ohio not so much is seen, yet in the Valley of East Tennessee, and especially in the western part of the State, there are superficial

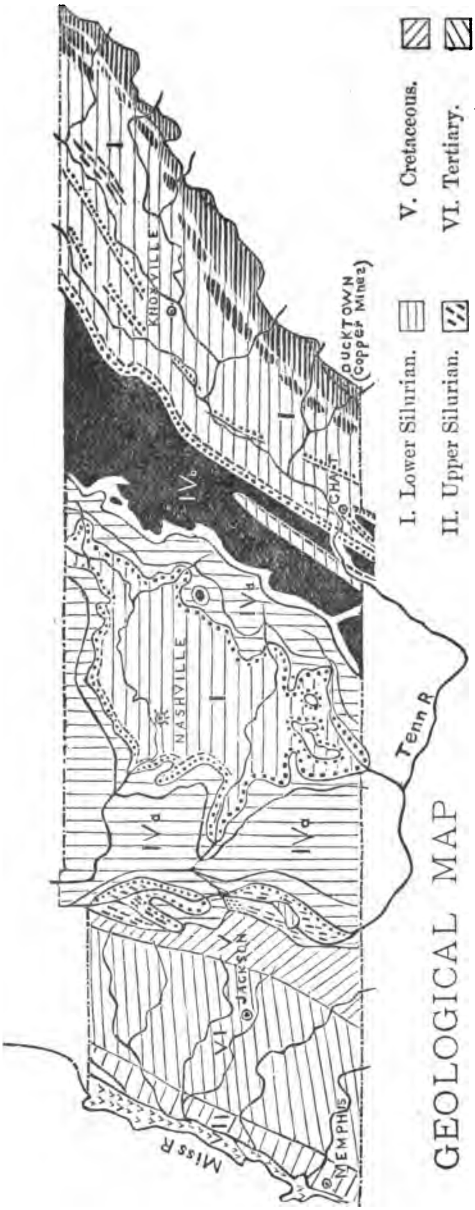
beds of gravel and sand which belong to the Drift, and constitute the formation called, in Tennessee Geology, the *Orange Sand.*

256. In this period also the climate was warm. The Mammals, so prevalent in the last age, reached their culmination; Bears, Hyenas, Tigers, Lions, etc., many of them larger than the species now living, made caves their dens; while huge Elephants, Mastodons, Sloth-like beasts (Megatheres), with Wild Boars, Horses, Oxen, and numerous other Quadrupeds, roamed over the lands. Some of these Mammals belonged to species which still have living representatives Many of the kinds are extinct. The Invertebrates of all kinds, as well as the plants, were the same in species as those now living.

257. In the *third* and last period the continents rose slowly to their present level; each great river washed out of the alluvial matter, with which the valleys had been filled, deep and deeper beds, in succession, leaving along its borders a series of beautiful terraces. Such terraces, covered with orchards and fields of grain, may be seen from the deck of a boat on the Ohio, and many other northern rivers, rising in steps from the bed of the stream back to the hills. (See the top part of the general section, page 109, in which terraces are represented.)

258. These periods of the Quarternary age have received special names. The first is the *Glacial;* the second, the *Champlain;* and the third, the *Recent,* or Terrace period. See also the general section.

259. Tennessee Formations and the Geological Map.—Confining ourselves to Tennessee, the great formations of the State are enumerated below, and some of their leading characteristics noticed. The principal descriptions will follow in the next chapter. The student

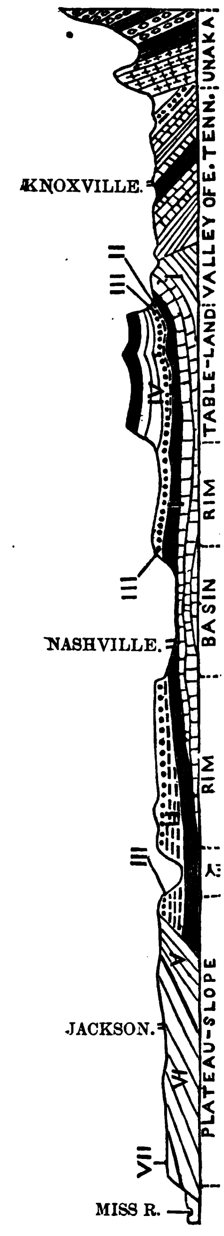


GEOLOGICAL MAP

OF

TENNESSEE.

SCALE, 75 MILES TO ONE INCH.



A Geological Section through Tennessee from North Carolina to the Mississippi River.

will be much assisted in understanding what is said about them, both here and elsewhere, by referring to the map on the opposite page.

260. This map shows the areas in which the formations respectively outcrop at the surface, and by comparing it with the map on page 9, it will be seen that most of these areas are nearly identical with the surface divisions of the State. On this page is a corresponding section of the formations, extending from North Carolina to the Mississippi river, through Knoxville, Nashville, and Jackson, and exhibits, in a general way, the relative position, dip, and manner of outcrop of the strata.

The formations are numbered both in the map and section as below. The two main divisions of the Silurian, on account of their importance, are considered as great formations.

261. I. Lower Silurian.—A vast series of strata the outcrops of which form more than one-third of the surface of the State, including all the surface of the Unaka Range, and very nearly all of that of the Valley of East Tennessee and the Central Basin.

The surface formed by the outcrop of these strata is indicated, on the map, by horizontal lines.

262. The entire thickness of these strata, measured directly through from top to bottom,

is, in this State, about 21,000 feet, or nearly *four miles*, which is three times greater than the aggregate thickness of all the other formations of Tennessee put together. If the strata were piled up in horizontal layers, and their edges exposed in a vertical wall, they would make a bluff four miles high.

The kinds of rocks of the Tennessee Lower Silurian, including the Metamorphic, are the same as those mentioned (p. 11) in paragraph 240, under *Silurian Age*. They are mainly hard, siliceous, and mountain-making strata in the lower and greater part, and softer calcareous and shaly strata in the upper. The different members of this great group will be described hereafter.

263. II. UPPER SILURIAN. — The strata of this formation outcrop within comparatively small areas of the State. It consists of four members, but, including all these, it is only about 1,300 feet in thickness. Its rocks are sandstones, shales, and limestones, with a few thin beds of the iron ore called *dyestone*.

The outcrops of the Upper Silurian rocks are indicated on the map by the short lines, or broken lines, which have generally a diagonal direction. The greatest area in which the rocks appear at the surface is in the Western Valley.

264. III. DEVONIAN.—The only representative of this formation in Tennessee is, as before stated, the *Black Shale*—a stratum of very dark, bituminous shale, rarely more than 100 feet in thickness, and generally much below this. In paragraph 169, page 75, it is described, and its outcrops given. On the map the outcrops are shown by the dotted lines.

265. IV. CARBONIFEROUS.—This great formation is well developed within the State. It has four mem-

bers or sub-divisions, and an aggregate thickness of about 3,700 feet. The *lower third*, embracing three members, is a *calcareous* division, the strata being comparatively pure limestone, or (at the base) a *calcareo-siliceous* rock, by which is meant a rock made up of both limestone matter and siliceous, or cherty, matter. The *upper two-thirds* is a *sandy* division, and is especially characterized by the presence of *bituminous* coal. The division consists of many strata of sandstone, with which beds of shale and coal are interstratified, the whole series constituting the *coal measures*.

266. The carboniferous strata are, as observed in paragraph 246, the surface rocks of the Highland Rim and the Cumberland Table-land.

Referring to the map, the area marked with *vertical* lines (IV*a*) has for its outcropping or surface rocks the calcareous division of the Carboniferous, and that printed *black* (IV*b*), the upper sandy division or the coal measures; the first is the area of the Rim, the latter that of the Table-land.

267. V. CRETACEOUS.—This is the third and uppermost division of the Reptilian age, and its only representative in Tennessee. The Cretaceous formation consists of beds of sand in its lower part, a gray or greenish calcareous stratum, more or less clayey and sandy, known as *Green sand* or *Rotten limestone* (paragraph 248), in its middle part, and sands and laminated clays above, the thickness of the whole being approximately 1,000 feet. The group is confined to West Tennessee. The area within which it

comes to the surface is indicated on the map by lines sloping to the right, and is numbered V.

268. VI. TERTIARY.—The beds of this formation are sands and laminated clays, with occasionally a local layer of the kind of coal called *lignite.* The estimated thickness of the group is 900 feet. It forms a large part of the surface of West Tennessee. Its area (VI) is represented on the map by lines sloping slightly to the right.

269. QUARTERNARY.—The Quarternary is a group including the sands, gravels, loams, alluvial beds, etc., which, where existing, overlie all other strata. The deposits of gravel, sand, mud, shells, etc., now forming in the rivers and elsewhere, are included in this group, but many of the beds were made long before modern time, as the phrase is understood in human history.

CHAPTER XI.

The Older or Paleozoic Formations of Tennessee.

270. The last chapter was devoted more especially to the *classification* of the ages and formations. In the first part of the chapter these were considered mainly with reference to the earth at large; then, commencing with paragraph 259 (p. 115), the names, general characteristics, and a map of the great formations occurring in Tennessee were given. It remains to study the latter formations more in detail.

271. By referring to the part of the general section on page 108, it will be seen that four of the formations, namely, the *Lower Silurian*, the *Upper Silurian*, the *Devonian*, and the *Carboniferous*, are included in *Paleozoic time.* They may, therefore, be considered together in one chapter.

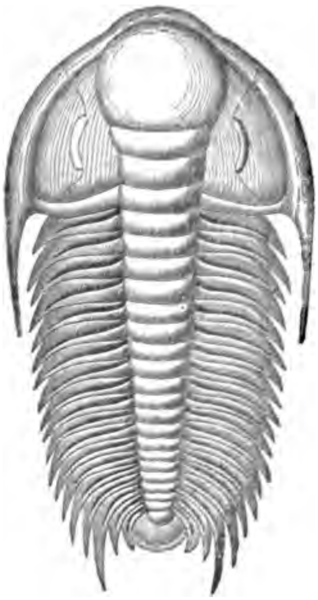
The strata of these formations are comparatively of great importance; they make up the great bulk of the rocks of the State, and, as may be seen on the map (p. 116), they outcrop (or would outcrop if the soil were removed), over more than three-fourths of its area; in them also are found most of the ores and minerals, all the true coal, marble, cement-limestone, etc.

272. The *Time* within which these strata were deposited is called Paleozoic, because the animals and plants, which lived during its long ages, were mostly different in kind from those that existed in the succeeding Time, and especially from those living now. During these ages, but not existing in succeeding ages, the tribe of *Trilobites* (p. 98) swarmed in the seas. The figure (28) on next page represents one of these *old-time* animals. It belongs to a genus called *Paradoxides*, some of the largest of which were twenty inches long. Other Trilobites are represented on pages 99, 127 and 000. Besides these, the old-fashioned Mollusks, called *Brachiopods* (pp. 97), and, in the latter part of the time, the *Ganoid fishes* (pp. 100, 101) were abundant, both tribes of which are now nearly extinct. So with many other families of animals and plants, though some which

are plentiful now began their existence then, as the *Sharks* among animals, and the *Pines* and *Ferns* among plants.

273. It will be observed that we do not include any *Archæan* rocks in the Tennessee series of formations. See paragraphs 238 and 239 (p. 111). In Canada the Archæan strata have the great thickness of 40,000 feet, and are divided into two formations as follows: the *Laurentian*, the lower and the older 30,000 feet thick, and the *Huronian*, the upper 10,000 feet. The place of this vast series is below our lowest outcropping rocks. They may be a part of the deep unseen foundation upon which our own formations rest.

Fig. 28.



I.—The Lower Silurian Formation.

274. This great series of strata has been briefly described in paragraphs 261 and 262 (pp. 117, 118). It is this which gives so much bulk to the Paleozoic rocks.

275 Sub-divisions.—The Lower Silurian strata of Tennessee are grouped into six divisions or minor formations as follows:

(1.) The *Ocoee Group*—A mass of mountain-making conglomerates and slates, 10,000 feet in thickness.

(2.) The *Chilhowee Sandstone*—Mostly a hard, whitish-gray sandstone, resting upon the last; also mountain-making, and 2,000 feet thick.

(3.) The *Knox Group*—The most important series of rocks in the Valley of East Tennessee. It has three sub-divisions: (*a*) *variegated sand-*

stones, at the bottom, 1,000 feet in thickness; (*b*) soft *variegated shales*, 2,000 feet; and (*c*) heavy beds of *dolomyte and limestone*, 4,000 feet.

(4.) The *Lenoir Limestone*—A blue soft limestone, 500 feet thick.

(5.) *The Lebanon Group*—Limestones and marbles resting upon the last, and not always easily separated from it; from 200 to 600 feet thick.

(6.) *The Nashville Group*—Calcareous shales and blue limestones, from 500 to 2,000 feet in thickness.

276. By referring to page 108, it will be seen that the first two of these Tennessee divisions belong to the *Primordial* period; the next two, to the *Canadian*; and the upper two, to the *Trenton*.

277. (1.) **The Ocoee Group (or Acadian).**—This is the great formation of the Unaka Range. Its area of outcrop is represented on the map (p. 116) by the shaded belt, or belt of thickened horizontal lines, lying along and touching the North Carolina boundary. It consists of a great thickness (10,000 feet, as stated) of hard conglomerates alternating with greenish, bluish, gray, and dark slates. All its rocks have been more or less changed by heat, or are *semi-metamorphic* (p. 61). The slates are, to some degree, *talcose*, and sometimes *chloritic* (p. 58). Dark roofing slates also occur among them.

278. The group is named *Ocoee* for the reason that its strata are grandly exposed in a deep, wild, and truly magnificent gorge, twelve miles long, which the Ocoee river has made in passing the Unaka Range. This gorge, or grand cut, is in Polk county, and the road to the copper mines of Ducktown passes through it. It is one of the cuts spoken of in paragraph 36 (pp. 26, 27). Other cuts also present splendid sections of the Ocoee rocks. The strata of the group are generally much folded and inclined.

279. Passing in an easterly direction, we find that along a line, nearly parallel with the Tennessee and North Carolina boundary, the rocks of the Ocoee group become wholly changed (metamorphosed) into granite-like rocks, gneiss, and slates of the micaceous and hornblendic kinds (pp. 66, 68). The line separating these changed rocks from the half-changed conglomerates and slates, is sometimes in Tennessee and sometimes in North Carolina, crossing the boundary at intervals. Thus it happens that Tennessee has several strips of these granite-like rocks within its borders. One of these is the Ducktown copper region, in the south-eastern corner of the State; another is in Cocke county; and a third, the longest strip of all, commences in Greene county, and extends through Washington, Unicoi, Carter, and Johnson, to the Virginia line. The great mountains in these counties, along the summits of which the State boundary runs, are made up of the changed rocks.

280. (2.) **The Chilhowee Sandstone (or the Potsdam).** Resting upon the last we have the *Chilhowee Sandstone,* a mass of gray, often light-colored sandstone, 2,000 feet thick. The layers are generally heavy-bedded, but interstratified, thin, sandy shales are sometimes met with. This is the formation of Chilhowee mountain, and of the other mountains making the interrupted line called the *Chilhowee Range* (paragraph 34, pp. 25, 26).

281. These mountains are obscurely indicated on the map (p. 116) by the detached shaded parts of the Unaka region. The one south of

Knoxville is Chilhowee mountain. The map on page 9 shows these skirting mountains more distinctly. To these the formation is mostly confined.

But few fossils are found in the Chilhowee strata. They abound, however, in curious straight rods, of the same material as the rock itself, not as large as pipe-stems but larger than wheat-straws. These rods belong to a genus called *Scolithus*, and are the fillings of worm holes made in the sand before it became consolidated.

We now pass from the hard mountain or Unaka strata to the upper, more or less calcareous, divisions of the Lower Silurian.

282. (3.) **The Knox Group (Calciferous and Quebec).** The rocks of the Knox Group (so called from Knox county and Knoxville) are confined to the Valley of East Tennessee, with the exception of a single small area on the Cumberland river, about 55 miles north west from Nashville, known as the *Well's Creek Basin*, and noticed below. They are of great importance in the Valley of East Tennessee. The rocks of very many of the valleys, coves, ridges, and plateau-areas, wild and cultivated, of this division of the State, making by far the larger part of its area, belong to this group.

283. The group is a triple one, having, as already stated, three divisions, as follows: (*a*) *variegated sandstones*, (*b*) *variegated shales*, and (*c*) a great thickness of *dolomytes and limestones*. We designate these respectively as (*a*) *Knox Sandstone*, (*b*) *Knox Shale*, and (*c*) *Knox Dolomyte*. The thicknesses of the several divisions have been given on page 123, in which, it will be seen, they are quite unequal. The thickness of the entire group is 7,000 feet. All the divisions are more or less calcareous; the Sandstone often contains interstratified layers of dolomyte and calcareous shale, and the Shale is generally calcareous.

284. (*a.*) **The Knox Sandstone (the Calciferous in New York and Canada).**—This division, found principally in narrow, sharp ridges, consists of sandstones of different colors, with some shales, and, as stated above, layers of dolomyte. The layers of sandstone are reddish, brown, gray, greenish, etc., and some of them very hard. The formation is of little importance so far as soil and agricultural character are concerned, but in some parts of the Valley of East Tennessee its rocks have had much to do in shaping the face of the country. Its hard sandstones have resisted the denuding forces, and have been left in characteristically sharp, roof-like and straight ridges, which we call *Knox Sandstone ridges.*

285. Such are *Webb's* (*or Rosebury's*) ridge, a few miles west of Knoxville, the so-called *Bays Mountain* forming the south-eastern boundary of Knox county, as well as *Beaver*, *Bull Run* and *Pine* ridges in the western and north-western part of the Valley. These ridges are some of those referred to in paragraph 46, page 30.

The surfaces of the rocks of this division often show fossil sea-weeds in abundance.

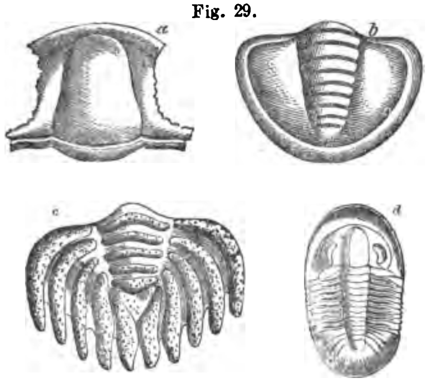
286. (*b.*) **The Knox Shale (Quebec).**—The Knox Shale is the formation of many long, beautiful, and generally rich valleys in East Tennessee. It is a group of variegated, brown, reddish, buff, and green clay shales, which are usually calcareous, and sometimes pass into limestones banded with clayey seams. It often contains layers of blue oolitic limestone, or *oolyte* (p. 63). Its thickness has been placed at 2,000

feet. Madisonville, Cleveland, and Rogersville are in good part located on this formation.

287. In the north-eastern part of the Valley of East Tennessee the threefold character of the Knox Group is not so well marked as in the western and sourthern parts. The sandstone division loses much of its distinctive character, and the shale becomes more calcareous.

288. Fossil shells and trilobites are found in some of the layers of the Knox Shale, especially in the limestone layers. The figure (29) on this page shows some of the forms of trilobites found in this formation.

Fig. 29.



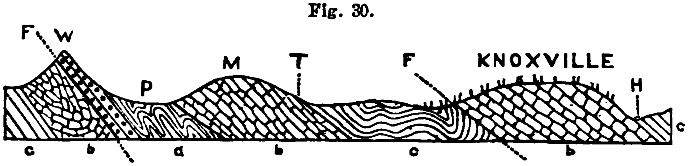
The cuts *a* and *b* are respectively the head and tail pieces of one which has been called *Bathyurus Saffordi.* The head *a*, however, is not complete. The cut *c* is the tail piece of one called *Amphion Barrandei*, and *d* is the entire animal of *Bathyurellus nitidus.*

289. (c.) **The Knox Dolomyte (also Quebec).**—Following the Shale we have this division, the most important of the Knox Group. With a thickness of 4,000 feet, it is by far the most massive calcareous formation in the State. Its strata are the rocks of

numerous ridges, as well as valleys, coves, and other areas in the Valley of East Tennessee.

290. The division consists of heavy-bedded layers of blue and gray dolomyte and limestone, the blue color prevailing in the lower part, and the gray in the upper. At the base the rocks are often oolitic in structure, contain trilobites, and are much like the blue oolitic limestone found in the Shale. The two divisions, in fact, run together; the blue limestones at the base of the upper one begins, in descending, to be interstratified with layers of shale, which become more and more predominant until the Shale is reached.

Fig. 30.



291. In its middle and upper part the Knox Dolomyte contains layers and masses of chert (p. 45). By the dissolving away of the dolomytes and limestones (an action which has been going on for hundreds of years), much of this chert, which does not dissolve like the strata enclosing it, has become free, and its angular fragments make a gray gravel that covers many ridges and knobby regions. This gravel forms many excellent roads. At some points large blocks of the chert are worked into millstones.

292. The section on this page (Fig. 30) illustrates the character of the rocks and how they lie at Knoxville, and for a few miles to the north-

west of Knoxville. It commences at Webb's ridge (W), extends through the ridge, M, and through Knoxville to the Holston river at H, a distance of about three miles. The strata, *b*, upon which the greater part of Knoxville rests, belong to the Knox Dolomyte. It will be seen that they form a ridge.

From the line F on the left of the cut to T we have a section showing the Knox Group and its three divisions. The dotted bands under W represent layers of the Knox Sandstone. These form the *sharp* Webb's ridge, one of the Knox Sandstone ridges (paragraph 285). Under P we have the Knox Shale, outcropping in a valley (Poor Valley). Under M are the rocks of the Knox Dolomyte. From T to the right hand F are rocks of higher formations, *Lenoir*, *Lebanon*, and *Nashville*. F and F are faults (p. 81).

The ridge M and the Knoxville ridge have the same formation. The first is called sometimes *Flint* ridge, on account of the abundance of loose chert upon it. These belong to the class of broad ridges noticed in paragraph 45, page 30.

293. Some of the Knox Dolomyte ridges are mentioned in the paragraph just referred to. Others are *Wallin's* ridge in the eastern part of Claiborne county, *Chestnut* and *Big* ridges (really parts of the same ridge) in Sullivan and Greene, and *Missionary* ridge east of Chattanooga. There are several of the same kind between Cleveland and Benton, the latter place being situated on one of them. Benton, Maryville, and Dandridge are on the same Knox Dolomyte range or ridge. An ill-defined ridge of this class extends from Greeneville to Newport, the former place being on its south-eastern side, and the latter on its north-western. Another of like character reaches from Russellville to Virginia, running between Rogersville and the Holston.

Just west of Washington, in Rhea county, is a wide range of Knox Dolomyte, which runs parallel with the eastern base of the Cumberland Table-land. There is also a wide one in Campbell and Claiborne counties. West of Decatur is one which, in its northern extension, lies on the east side of Kingston, etc.

The Knox Dolomyte is the formation of Blountville and Jonesboro, of Morristown, Mossy Creek, New Market, Loudon, and Charleston, and

in part of Tazewell, Kingston, and Chattanooga. It outcrops extensively in Sequatchee Valley. Pikeville and Bridgeport are upon it.

294. The Wells Creek Basin.—The Knox Group is only seen, as we have stated, in the Valley of East Tennessee, excepting within the *Wells Creek Basin* (paragraph 281). This curious basin lies on the south side of the Cumberland river, in the eastern parts of Stewart and Houston counties. It has an oval form, and includes an area of six or seven square miles. Its existence is due to the uplifting of the strata in a high dome, the top of which has been worn and washed away. The uplifting of the strata and the subsequent washing or denudation have been sufficient to expose the upper gray part of the Knox Dolomyte.

295. It may be stated here, once for all, that in this basin the other formations outcrop in rings around the Knox Dolomyte very much as the layers of an onion *outcrop* on a fresh surface made by cutting off a slice. The Silurian strata and the Devonian Black Shale make the floor of the basin, and these are inclosed in a circle or hilly rim of carboniferous limestone.

The carboniferous rocks outcropping along the Cumberland river, for several miles both above and below the Wells Creek Basin, are very much disturbed, and dip at various angles.

296. (4.) **The Lenoir Limestone (Chazy, in New York and Canada).**—This name we give to a stratum of blue shaly limestone which lies next above the Knox Dolomyte. It is well exposed in a quarry in front of Lenoir's Station on the East Tennessee and Georgia railroad, hence the name. Its greatest thickness is 600 feet.

297. In the north-eastern part of the Valley, or in Cocke, Greene, Washington, Carter, and Sullivan counties, it is much reduced in thickness, often to 100 feet. It also becomes more compact. In the western part, that is the part of the Valley next to

the Cumberland Table-land, it is not separated from the overlying limestone of the next formation by any well marked characters.

In the northern part of Jefferson county, and in the vicinity of Bull's Gap, it is often knotty in structure, breaks up into small blocks, and abounds in fragments of trilobites.

298. The Lenoir limestones is well filled with fossil shells, corals and sponges. They contain especially a large sea-snail (called *Maclurea magna*), which is flat on one side, and frequently four and five inches across. On account of the abundance of this fossil the Lenoir limestone bears the name of the *Maclurea limestone* in the Report on the Geology of Tennessee.

299. This limestone may be regarded as an East Tennessee formation. It lies along the eastern base of the Knox Dolomyte ridge upon which Knoxville is built. The depot at *Strawberry Plains* is upon it, and it may be seen filled with the big sea-snail at *Kingsport*, in Sullivan county.

300. (5.) **The Lebanon Group (Trenton).**—The prevailing rocks of this group are blue and dove-colored fossil-bearing limestones. They are mostly thick-bedded, but thin-bedded flaggy strata occur. In the region of Knoxville they are gray, reddish, and variegated marbles.

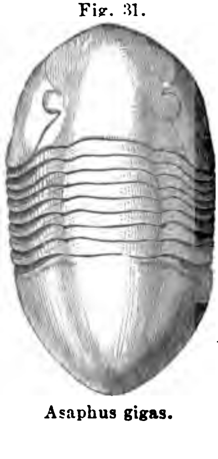
The formation belongs to both Middle and East Tennessee. Its strata are the bottom rocks in the Central Basin—the first of the Lower Silurian exposed in this division of the State. They are 500 feet thick, outcrop over a large part of the Basin, and yield a strong and fertile soil.

301. One of the thin-bedded or flaggy strata of the Lebanon Group, not far from 100 feet thick, and called the *Glade limestone*, is the rock of the "*Cedar glades*" of the Central Basin, upon which the noted cedar forests of this part of the State grow.

302. The rocks of the formation are well displayed about *Lebanon*, the county seat of Wilson, which circumstance has given name to the group. Other towns in the Basin located upon these rocks are Murfreesboro, Shelbyville, Lewisburg, Woodbury, Campbellville in Giles, the lower parts of Columbia, Liberty in Smith, etc. The whitish gray limestone on Carter's creek in Maury, most of the bluffs of the Cumberland river, commencing just above Nashville and extending up at least as far as Carthage, are made up of Lebanon rocks.

303. Passing to the Valley of East Tennessee, we find the Lebanon rocks, closely associated with the Lenoir limestone below and the Nashville above, coming out from under the Table-land and outcropping in the minor valleys along its eastern base. They occur also in all the blue limestone valleys nearly as far as Knoxville, retaining pretty much the same character they have in the Central Basin.

Fig. 31.



Asaphus gigas.

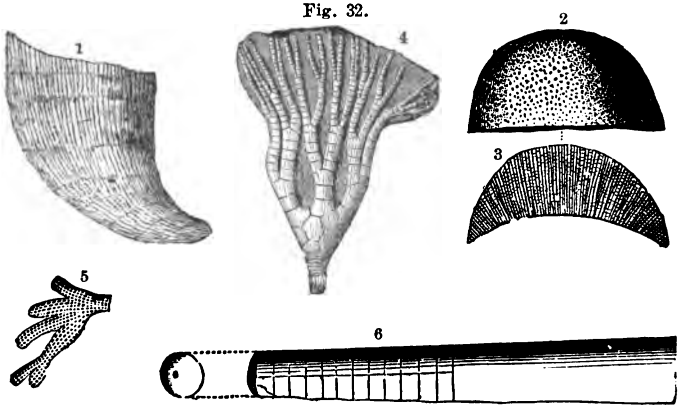
304. In the southern part of the State before reaching the eastern base of the Table-land (here called Walden's ridge, p. 32), they appear in Sequatchee Valley. See the section on page 87, in which the band numbered V represents the Lebanon rocks, together with those of the Lenoir and Nashville formations.

305. In the vicinity of Knoxville the Lebanon rocks become quite different in character. Here the group

is mainly represented by heavy-bedded strata of marble, altogether nearly 300 feet thick.

This marble is a variegated *crinoidal* and *coralline* limestone, much of it beautiful, and extensively quarried. (See part V.) *Crinoidal* limestone is defined in paragraph 205, pages 95 and 96. A *coralline* limestone is similar, excepting that it is made up of coral instead of crinoid-fragments. The belt of marble runs lengthwise pretty well through the middle of the Valley of East Tennessee.

Fig. 32.



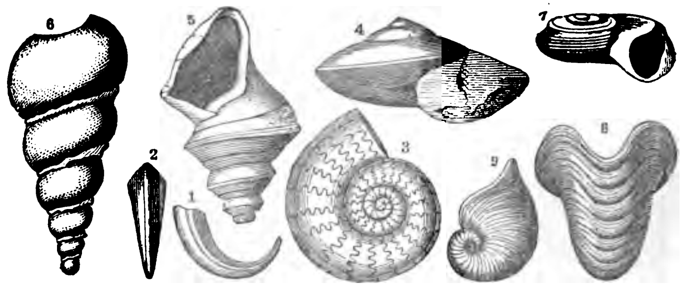
Radiates.—1. Petraia corniculum; 2, 3. Chætetes lycoperdon; 4. Lecanocrinus elegans. *Mollusks.*—5. Ptilodictya acuta; 6. Orthoceras junceum.

It is found as high as Hawkins county, and as far south as McMinn and Bradley. On the eastern side of the Valley the marble disappears, the Lebanon group blending with the Lenoir, and becoming thin and unimportant.

306. The rocks of this group are well filled with fossils. These are mostly marine Mollusks, Corals, and Trilobites. No remains of fishes or land animals are found. In Figs. 31, 32, and 33, are representations of some of the fossil forms met with and characteristic of the group.

307. The Nashville Group (Cincinnati Group).—The rocks of this group outcrop extensively in both the Central Basin and the Valley of East Tennessee. In the Basin they are about 500 feet thick, and are mainly blue limestones, full of fossil shells, corals, etc.

Fig. 33.



Mollusks.—1, 2. Cyrtolites Trentonensis; 3. Cyrtolites compresses; 4. Pleurotomaria lenticularis; 5. Murchisonia bicincta; 6. Murchisonia bellicincta; 7. Helicotoma planulata; 8, 9. Bellerophon bilobatus.

It will be observed that the rocks within the Basin are limestones, making a series 1,000 feet in thickness, divided equally between the Lebanon group and the one under consideration.

308. In the western part of the Valley of East Tennessee the Nashville rocks preserve about the same features which they have in the Basin, excepting that they include more shale. But in the eastern part of the Valley they become chiefly a great series of *sandy calcareous shales* nearly 2,000 feet thick.

The formation in both East and Middle Tennessee is an important one, and gives the State some of its best farming regions.

309. Nashville is built upon strata of this group, and hence the name the latter bears. It is also called the *Cincinnati group* for a like reason, the hills about that city containing rocks which are the northern extension of the same beds.

The following section of the strata, as they exist in and about Nashville, will serve to illustrate the general character of the rocks of the group. It commences with the lowest and ascends.

(*a.*) LEBANON GROUP. The upper strata seen in the base of the hills in the vicinity of Mt. Olivet Cemetery, on the Lebanon turnpike. They may be studied in the valley of Mill creek, on the Murfreesboro turnpike.

(*b.*) NASHVILLE GROUP:

(1.) *A stratum of blue, siliceous or sandy limestone*, about 60 feet thick. It often weathers into shale, or shale and flaggy limestone. This is in the water under the wire bridge, but rises in going down the river, and may be studied in the bluff below the railroad bridge. It outcrops in the suburbs of the city on the Murfreesboro road.

The stratum abounds in a flat shell, about as large as a dime, belonging to the genus *Orthis* (*O. testudinaria*), and for this reason has been called the *Orthis bed*. The shell is No. 8 in Fig. 34.

(2.) Next above is a *laminated light blue limestone*, 25 feet thick, often resembling a sandstone. It is, in fact, a hardened bed of limestone sand which has been drifted by water and arranged in thin layers, the sand in great part ground particles of broken shells. It is near the water under the wire bridge, and outcrops at various points about the city. The rock is easily quarried in smooth layers, and is extensively used for building purposes. It is the rock used in the construction of the Capitol, and has been called the *capitol limestone.*

(3.) The *Dove Limestone.* A number of layers, 11 feet thick in all, most of which are compact, fine-grained, dove-colored limestone or marble. The dove-colored part is brittle, breaking with a shell-like fracture, but is a durable building stone. It may be seen in the bluff under the wire bridge, in the bank of the river at the foot of Gay street, just beyond the water works, and at other points.

(4.) Then above are *layers of the common kind*, 25 feet thick. This division is like No. 6.

(5.) Resting upon the last is *a remarkable bed* of light yellowish-gray coarse limestone, made up in great part of the valves of a sea-muscle called *Cyrtodonta* (C. Saffordi). It is the *cyrtodonta bed.* It outcrops boldly in the bluff at the wire bridge as a single solid layer, 10 feet thick. It may be seen at the water works and elsewhere.

(6.) This division embraces *the upper rocks at the city*. Its layers, including those of No. 4, are the common rocks of Nashville, and may be taken as the types of the rocks of the Nashville formation throughout the Central Basin. They may be seen outcropping around the capitol grounds, where they present a thickness of 120 feet, also on college hill, at the water works, etc. When freshly quarried, the rocks are dark-blue, coarse-grained, often roughly stratified, having more or less shaly laminæ, and full of fossils. They weather generally into rough flaggy limestones, with some shaly matter, often liberating multitudes of fossils, especially small corals.

A bed of reddish marble exists in Franklin county at the top of the Nashville group.

310. The first and lowest member of the section above, the *Orthis bed*, is a persistent one, and is seen at many points in the Central Basin. A good exposure is at Franklin in the bank of the river below the bridge. It also appears, at a low level, in the Western Valley of the Tennessee river, in Hardin and Wayne counties. It outcrops in the bed and banks of the Tennessee river, and of several creeks in those counties, and is quarried and burned for making *hydraulic cement.* A fine exposure exists near Clifton on the bank of the Tennessee, at which point works for manufacturing cement are in operation.

311. We may add here that the Orthis bed is the only part of the Nashville group which retains its thickness in the region of Clifton. All above, so well developed at Nashville, is reduced to a rough bed of limestone and a bed of shale, both together hardly 40 feet thick.

312. The following are some of the towns located upon rocks of the Nashville Group: Gallatin, Hårtsville, Dixon Springs, Gainsboro, Franklin, the upper part of Columbia, Mount Pleasant, Pulaski, and Fayetteville.

313. The change which takes place in the character of the Nashville rocks in passing from the western side to the eastern side of the Valley of East Tennessee, has been mentioned in paragraph 308.

On the western side these rocks, associated with the Lenoir and Lebanon limestones (paragraph 303), and in effect making a single group with them, are the rocks of many long rich limestone valleys, as *Beaver creek, Raccoon, Hickory, Big, Powell's,* and more to the south, *Savannah, Tennessee,* and *Lookout* valleys. On each side of Sequatchee Valley also is a minor valley in which these rocks occur. Including the Lenoir and Lebanon, as above, we find among the towns located upon them *Tazewell, Jacksboro, Clinton, Washington, Decatur, Georgetown,* and in part, *Chattanooga.*

314. In the region of Knoxville the shale of the Nashville group is predominant, though flaggy limestones are still met with. Further east the mass becomes almost wholly shale, including a few thin sandstones, and rarely a thin layer of limestone. This

shale, nearly 2,000 feet thick, as before stated, is calcareous, sometimes sandy, has a sky-blue color when freshly quarried, and a yellowish, or a dull drab, or gray, when weathered.

315. It is the rock of the remarkable *knobby region or belt* which commences at the Virginia line just above Kingsport, in Sullivan, and extends nearly to the Hiwassee river in McMinn county. This belt of knobs widens out around the Bays mountain group of ridges, covering parts of Sullivan, Green, and Hawkins, and then reaches through parts of Jefferson, Cocke, Sevier, Blount, and Monroe to McMinn. *Sevierville* is within the belt, and *Newport* on the eastern edge of it. The knobby belts between Blountville and Holston mountain are also made of the shale.

316. There is another great knobby belt of this shale, west of the one mentioned, containg *gray* knobs like the other, but in addition long lines of *red* knobs. This belt commences in the region of Strawberry Plains, extends through Knox county, the western parts of Blount and Monroe, through McMinn and Bradley, nearly or quite to the Georgia line. The principal line of red knobs is referred to on pages 30 and 31, commencing at the bottom of 30.

317. The lines of red knobs are primarily due to the presence in the shale of several beds of a *hard, dark limestone* containing much iron, and called the *Iron limestone.* It is an *interpolated* rock, or a local rock, inserted in the main series of shales. At some points it becomes an iron ore.

318. Another interpolated bed is found in the same shales. It is a stratum of *brown* or *brownish-red calcerous shale,* which becomes, at some points, variegated *marble* (the upper marble). This bed is seen as a member of the Nashville group in many valley-ranges. It appears as marble in Knox county east of Knoxville, and as red shale west of that city. Some of this shale has been manufactured into hydraulic cement.

319. The following section of the strata in the vicinity of Knoxville (best seen in going east from the city), will show the order and character of the

beds mentioned, and also the relation of the Nashville group, as a whole, to the formations below it. Like the other sections given, it is arranged in the ascending order:

(*a*.) KNOX DOLOMYTE. The rocks upon which Knoxville is chiefly built. (p. 127.)

(*b*.) LENOIR LIMESTONE. Blue argillaceous limestone. 500 feet (p. 130).

(*c*.) LEBANON GROUP. Marble beds 380 feet (p. 131).

(*d*.) NASHVILLE GROUP:

(1.) *Calcareous bluish shale* mostly, but containing interlaminated layers of flaggy and iron limestone, 400. The shale is buff or grayish in its weathered condition.

(2.) *Iron Limestone*, weathering often to a porous dark-brown sandy material. Some of it affords flags for paving purposes. 250 feet. The Iron limestone is highly fossiliferous.

(3.) *Calcareous Shale*, with more or less flaggy fossiliferous bluish limestone, about 500 feet. The shale, like No. 1, is bluish, weathering buff or gray.

(4.) *Red Marble* (*Upper Marble*). Variegated, mostly red, 300 feet. As stated, this division is often brown or brownish-red shale.

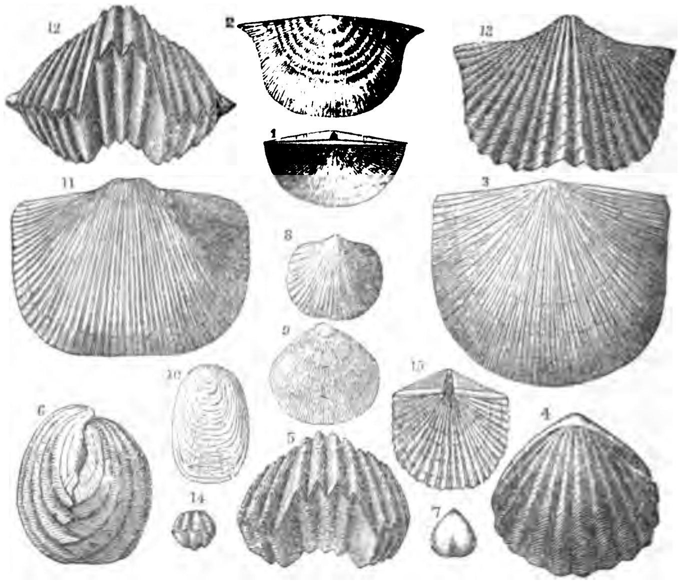
(5.) *Calcareous Shale*. The topmost portion. Bluish shale, weathering like 3, containing flags of limestone. Thickness uncertain, owing to the folded condition of the layers—about 400 feet.

320. The fossils of the Nashville group resemble those of Lebanon group next below. Some are common to both. On the next page we have representations of some of the shells found in the Nashville rocks. Nos. 4, 5, and 6 are different views of the same shells; so are 12 and 13. Nos. 1 and 14 are also found in the rocks of the Lebanon group.

The coral, Nos. 2, 3, in Fig. 32 (p. 133), and the shell, 5, in Fig. 33

(p. 134), are abundant and common, both in Lebanon and Nashville rocks. What is said in paragraph 314 in reference to the absence of fish remains applies here.

Fig. 34.



Mollusks, and all *Brachiopods*—1. Leptæna sericea; 2. Strophomena (Leptæna) rugosa; 3. Strophomena alternata; 4. 5, 6. Rhynchonella capax; 7, 14. Rhynchonella (?) bisulcata; 8. Orthis testudinaria; 9. Obolus filosus; 10. Lingula quadrata; 11. Orthis occidentalis; 12, 13. Orthis lynx; 15. Orthis tricenaria.

321. Minerals and Ores of the Lower Silurian.—These are properly considered in Part V. The Ocoee group and the Knox Dolomyte are the principal mineral-bearing formations. The first yields some gold, also copper and iron ores; the Knox Dolomyte contains many veins, mostly small, of lead ores, zinc ores, and barite or heavy spar. In this also are found iron ore, calcite, dolomyte, crystals of quartz, pyrite,

fluor spar, and other minerals. The Nashville and and Lebanon rocks are much like the Knox Dolomyte in their mineral bearing character, the minerals being much the same.

II.—The Upper Silurian Formation.

322. The general character of the Upper Silurian formation, as found in Tennessee, is given on page 118. Its *aggregate* thickness is only about 1,300 feet, which is but *one-sixteenth* of that of the Lower Silurian. At no one point is it more than 800 or 900 feet.

323. In the Valley of East Tennessee two of its members outcrop in long belts, which are generally either long and straight mountains or ridges, and so narrow that they can only be represented on a small map by lines. In the map on page 116 the broken lines, mostly accompanied with a line of dots (the Black Shale), represent these belts. In the Central Basin also the outcrop is very narrow, but in the Western Valley (p. 36) one of the members spreads out and appears over a considerable area.

324. The Upper Silurian has four members or divisions, two of which are confined to East Tennessee, one to Middle and West Tennessee, and one occurring in all three parts of the State. On the eastern side of the Central Basin the Upper Silurian rocks are *wholly absent*, the Devonian formation (Black Shale) resting directly on the Nashville group of the Lower Silurian.

The following are the divisions, arranged in the ascending order:

(1.) The *Clinch Sandstone*—A group of sandstones with shales, from 500 to 700 feet thick; the sandstones are mountain-making, and the group is confined to the Valley of East Tennessee.

(2.) The *Dyestone Group*—A series of variegated shales, with thin sandstones, from 100 to 300 feet thick; contains from one to three layers of the red iron-ore called *dyestone*. It is also an East Tennessee formation, and is mostly found in ridges.

(3.) The *Clifton Limestone*—Best developed in the Western Valley, where it is 200 feet thick, but outcropping on the western side of the Central Basin, and occurring in East Tennessee. It is chiefly a gray fossiliferous limestone, its lower part, however, in the Western Valley, is variegated (red and gray) limestone and marble.

(4.) The *Linden Limestone*—Blue, highly fossiliferous limestone; its greatest thickness, 100 feet. It occurs west of the Central Basin, and in the Western Valley.

325. By referring to the section on page 108, it will be seen that 1, 2, and 3 of these divisions are included in the American *Niagara* Period, and that 4 is equivalent to the *Helderberg*. The *Salina*, a New York formation of shales, marls and impure limestones, having a maximum thickness of 1,000 feet, and the *Oriskany*, a sandstone formation of the northern states, have no representatives in Tennessee. The Salina rocks of New York are impregnated with salt water, from which large quantities of salt are manufactured annually.

326. (1.) **The Clinch Sandstone (Medina in New York.**—This follows, where existing, next above the Nashville group. In the northern part of the Valley of East Tennessee it consists chiefly of two strata, a *red shale* below and a hard *gray sandstone* above, each having a thickness of about 400 feet. The gray sandstone is very conspicuous in *Clinch* mountain (paragraphs 43 and 44, pp. 30, 31), of which it forms the crest and south-eastern slope.

Had this sandstone been a soft rock, the strata forming the mountain

would have long since been worn away (p. 87). The red shale outcrops just below the crest on its north-western side, and dips to the south-east under the sandstone. The shale has been protected from denudation by the sandstone above it. But few fossils comparatively are found in these rocks.

327. The Clinch sandstone, with more or less of the red shale, occurs also in a number of the mountains of upper East Tennessee, the structure of which is much like that of Clinch. Among these are the *Bays Mountain ridges*, the *Devil's Nose* in Hawkins, *Powell's Mountain*, *Lone Mountain* in Claiborne and Union, and *House Mountain.*

328. In the southern part of the Valley the Clinch formation becomes a series of sandstones and shales of many colors—gray, reddish-brown, buff, and greenish. These rocks are found in *White Oak* mountain (p. 30), where they have a thickness of 500 feet, and outcrop on the summit and eastern side of the mountain. Some of the layers abound in fossils.

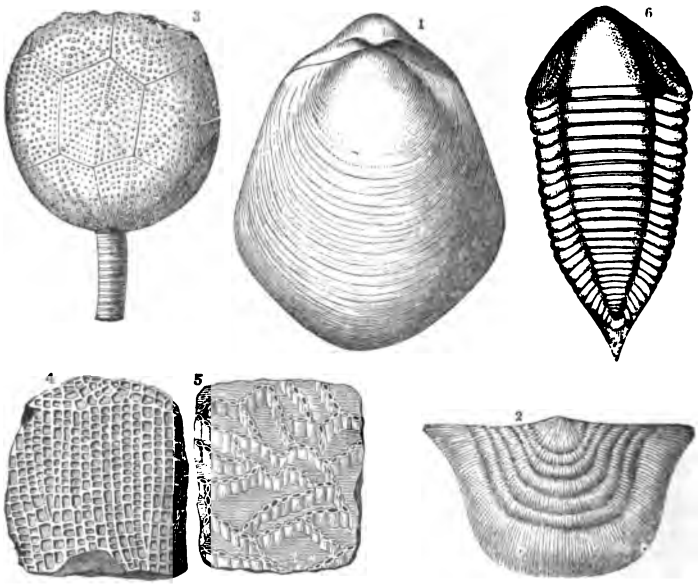
329. (2.) **The Dyestone Group (Clinton in New York).**—This East Tennessee formation is a series of variegated shales and thin sandstones, of brown, reddish, and pale-green colors. Much of the mass is calcareous; at some points limestones occur. The group owes its importance and its name to the *dyestone* iron-ore which it contains. These beds of ore are fossiliferous, and from a few inches to three (rarely more) feet in thickness. (See p. 64; also Part V, p. 183 and on.)

330. The Dyestone group, with two subordinate formations to be mentioned (the *Black Shale* and the *Barren group*), constitute a *trio* of formations which form a number of small, but long and characteristic, ridges

—*Dyestone ridges*—in the western part of the Valley. One of these lies immediately at the base of the Cumberland Table-land, and extends almost continuously from Virginia to Georgia. Such ridges are also found in Sequatchee Valley.

331. (3.) **The Clifton Limestone (Niagara Sub-division).**—Of the Upper Silurian divisions this is the most generally distributed, and yet it is wholly absent

Fig. 35.



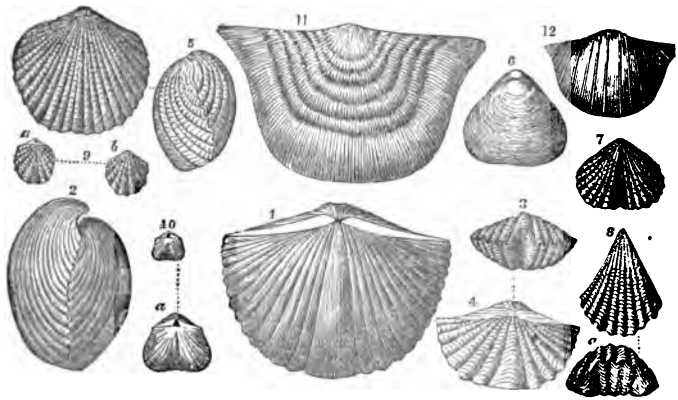
Crinoid.—3. Caryocrinus ornatus. *Corals.*—4. Favosites Niagarensis; 5. Halysites catenulata. *Brachiopods.*—1. Pentamerus oblongus; 2. Strophomena rhomboidalis. *Trilobite.*—6. Homalonotus delphinocephalus.

from many sections of the State. It is, in the main, thick-bedded fossil-bearing limestone, sometimes containing clayey layers, and weathering into shale. In the

Western Valley, the region of its greatest development, it is equally divided into a lower variegated (often affording a fair marble) and an upper gray limestone, each in Wayne county, 100 feet thick.

Clifton, on the Tennessee river in Wayne, is located upon the lower part of the formation. In the region of this place the rocks of the formation can be studied to advantage, and hence the name we give it.

Fig. 36.



Brachiopods.—1, 2. Spirifer Niagarensis; 3, 4. Spirifer sulcatus; 5 (two views) Atrypa nodostriata; 6. Merista nitida; 7, Anastrophia interplicata; 8 (two views) Rhynchonella cuneata; 9. *a*, *b*, Leptocœlia disparilis; 10. *a*, Orthis bilobus; 11. Strophomena rhomboidalis; 12. Leptæna transversalis.

332. The rocks of the Clifton formation make the "glades" in Perry, Decatur, Wayne, and Hardin counties; among them are the gray rocks of *Savannah*, the marble of the Big Sandy in Henry county, and of Birdsong creek in Benton; the limestone below the Black Shale at *Centreville.* On the western slopes of the Central Basin and in the ridges east of *Pulaski* it occurs, at many points, below the same Black Shale.

333. In East Tennessee it is the limestone on the south-west side

of *Sneedville;* a strip of it lies at the eastern base of Newman's ridge, and another at the eastern base of Powell's mountain.

334. The glades of the Western Valley have supplied many fossils from this formation, some of which are represented in Figs. 35 and 36. They are especially noted for *crinoids* and *sponges.* In the Report on the Geology of Tennessee the Clifton formation is named the *Meniscus Lime-*

Fig. 37.

stone, for the reason that it contains, in great abundance, a fossil sponge shaped like the glass lens called *meniscus.* In Fig. 37 the side, and in Fig. 38 a cross section, of this curious sponge are represented.

Fig. 38.

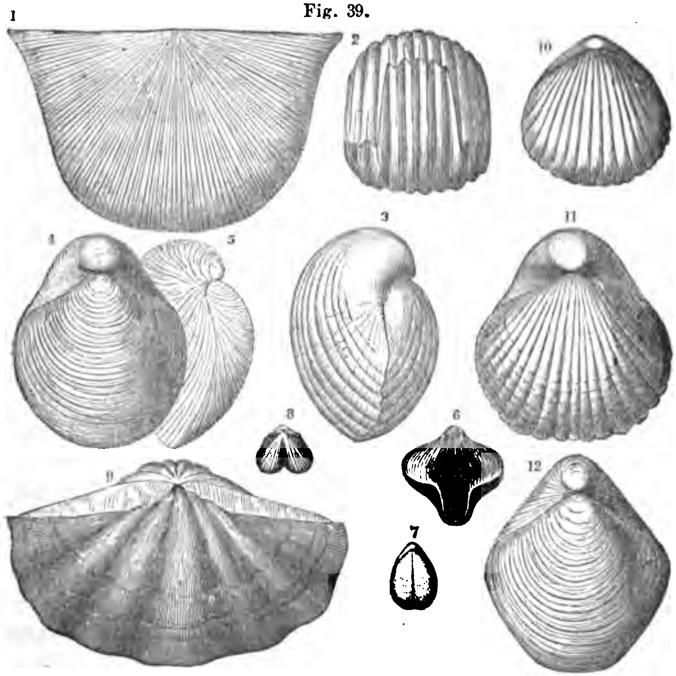
Fossil Sponge.—Figs 37, 38, Astræospongia Meniscus.

335. (4.) **The Linden Limestone (Helderberg).—This** limestone, like the last, has its greatest **development** **in** the Western Valley. It is a stratum of **blue,**

thin-bedded, and sometimes shaly limestone, which is remarkably full of fossils. The rock at some points contains flinty layers, especially in its upper part.

The formation is seen below the Black Shale at *Linden*, in Perry county, and outcrops at other points in the valley of Buffalo river, as well as of Duck river. It occasionally appears outcropping on the western slopes of the Central Basin, but here it is thin and often absent. East of this it has not been observed.

Fig. 39.



Brachiopods.—1. Hemipronites radiata; 2, 10. Rhynconella ventricosa; 3, 11. Pentamerus galeatus; 4, 5. Pentamerus pseudo-galeatus; 6. Eatonia singularis; 7. Meristella sulcata; 8. Orthis varica; 9. Spirifer macropleura; 12. Meristella levis.

336. The Linden limestones are seen in several blue shaly limestone bluffs on the Big Sandy, in the heads of the hollows about *Decaturville*, about the *White Sulphur Springs* in Hardin county, and at points (though generally absent) above the Clifton limestone in the valleys of Indian and Hardin creeks in the same county. They are found also resting upon the Clifton rocks in the bluff below Cumberland City on the Cumberland river, and at the foot of the hills around the Well's Creek Basin. Fig. 39, on the preceding page, is a group of some of the characteristic fossils of the Linden limestones.

337. Fossils of the Upper Silurian.—These are much like those of the Lower Silurian. (See paragraphs 240 and 320, on pages 111 and 139 respectively.) Remains of fishes have been found in the upper part of the Silurian of Europe, but not of America.

338. Minerals.—The Upper Silurian rocks of Tennessee, with the exception of the iron ore mentioned, afford but few minerals. The Clifton limestone contains some small veins of lead ore, crystals of pyrite, and a little petroleum.

III.—The Devonian Formation.

339. The Devonian formation is more poorly developed in Tennessee than the Upper Silurian. Its only representative, as stated on page 118, is a stratum of bituminous shale, already several times referred to, and bearing the name below.

340. The Black Shale (Genesee Shale).—The *Black Shale* of Tennessee is apparently the southern extension of a division of the Hamilton period, called, in New York, the *Genesee Shale*. It has been sufficiently described in paragraphs 169 and 264, on pages

75 and 118, to which the attention of the student is directed.

341. The great extent of this Shale, or the persistency with which it spreads over the country without thinning out, is one of its remarkable characteristics. It is always to be found when its proper horizon or its place in the series of formations is presented at the surface. In this respect it is quite in contrast with the members of the Upper Silurian, which exist in certain parts of the State only, or, we may say, exist in patches or in strips.

342. The Black Shale contains *pyrite* (p. 197), which unfits it for use as a roofing slate, but makes it a material from which copperas and alum may be manufactured. It also contains *bitumen*, but in thin leaves, rarely an inch in thickness. What is said in paragraphs 135 and 136, on page 65, will apply to this Shale.

343. In addition to its outcrops, mentioned on page 75, it appears in East Tennessee along the eastern base of Powell's Mountain, of Newman's Ridge, Clinch Mountain, and, in the southern part of the State, White Oak Mountain; also in front of Montvale Spring, near the base of Chilhowee mountain; also in the dyestone ridges generally, including those in Sequatchee Valley.

344. Fossils.—The Black Shale contains the first remains of land plants (wood, etc.) found in Tennessee. It affords also a few shells and traces of fishes. The kind of life existing when the Devonian rocks were deposited, or during the Devonian Age, is mentioned on page 112.

345. The Devonian Out of Tennessee.—In New York, Pennsylvania, and the northern part of Virginia, the Devonian formation is greatly developed, the aggregate thickness of its strata being not far from 10,000 feet. This is not the thickness at any one point, but the sum of the greatest thicknesses of its members. In the section on page 108 the four members or periods of the American Devonian are given. All

of these, with the exception of the *Corniferous*, which is chiefly limestone, are made up of shales and sandstones, and all, except the *Hamilton* (so far as it is represented by the comparatively thin Black Shale), thin out and disappear before reaching Tennessee.

The Corniferous limestone extends further south-west than any of them, as it is found outcropping in the region of Louisville, Kentucky. There are, indeed, doubtful traces of the Corniferous in certain parts of Tennessee, but they are so thin and local that we need not regard them here.

IV.—The Carboniferous Formation.

346. The general character, kinds of rocks, number of divisions and areas of the carboniferous formation, have been given in paragraphs 265 and 266, commencing on page 118. Its strata are the surface rocks, as there stated, of two of the large natural divisions of the State, the Cumberland Table-land and the Highland Rim. This makes more than one-fifth of the entire surface of the State *Carboniferous;* that is to say, showing carboniferous rocks, or having them immediately beneath the soil. This alone would give great interest to the formation, as the character of the soil depends greatly upon the nature of the underlying rocks. But in addition, the upper member of the formation contains all the coal beds, and these are vital to many interests.

347. The divisions of the Carboniferous formation, commencing with the lowest, are as follows:

(1.) The *Barren Group*—The base of the Carboniferous series; rocks generally more or less calcareous, but distinguished by containing *much siliceous or flinty matter;* greatest thickness 300 feet, but often much less.

(2.) The *Coral, or St. Louis Limestone*—Gray and blue, thick-bedded, fossil-bearing limestones, usually with imbedded nodules of flint or chert; 250 to 300 feet thick.

(3.) The *Mountain Limestone*—Also gray and bluish fossiliferous limestones; forms the base of the Cumberland Table-land; from 300 to 700 feet thick.

(4.) The *Coal Measures*—A great series of sandstones, shales, and beds of coal interstratified; generally from 500 to 600 feet thick, but in the north-eastern part of the Table-land 2,500.

348. (1.) **The Barren Group.**—In Middle Tennessee this group includes the rocks of the elevated "barrens" which lie on both sides of the Central Basin and make a part of the Highland Rim. Its rocks, which are often layers of flint, are seen next above the Black Shale wherever the Rim breaks off into valleys and gorges. Many beautiful water-falls are formed by the passages of streams from the highlands over these hard rocks, down into "gulfs" or gorges.

The general outlines of the Central Basin are sharply defined by the flinty and siliceous rocks of the Barren Group (p. 88), as well as the outlines of the Western Valley, especially on its eastern side.

349. At many points the rocks of the formation are flinty layers, with silico-calcareous and bluish shale; at others they are mainly such shale: at others, again, layers of limestone occur, which are frequently crinoidal limestones (p. 96), and, at certain localities, have supplied geologists with many fine specimens of crinoids. In the southern part of the State the member becomes thin, and blends with the coral limestone above.

350. In the Valley of East Tennessee the Barren Group, closely associated with the coral or St. Louis Limestone, is one of the trio of formations making the *dyestone ridges* (paragraph 330, p. 143), in fact the ridges owe their existence, as such, to the flinty layers of this group.

At Cumberland Gap, and in the first ridge east of Clinch mountain, a thick greenish shale occurs in the horizon of this group, which is filled with a peculiar sea-plant called, from its feathery form, the cock-tail sea weed.

351. (2.) **The Coral, or St. Louis Limestone.**—This limestone, called *coral* on account of the frequent occurrence of a large fossil coral in it, and *St. Louis* for the reason that corresponding layers outcrop about that city, is, with the beds of the Barren Group, the surface or cap formation of the Highland Rim. In the flat wooded regions immediately around the Central Basin the rocks of the Barren Group are first met with, but going further back from the Basin the overlying layers of the St. Louis begin to appear. At the same time the character of the country changes, the soil becomes red and much more fertile, presenting, indeed, some of the best farming regions of the State. The same change takes place in going in an easterly direction from the Western Valley.

352. A wide belt of country lying at the western base of the Tableland, and including the towns of *Livingston, Cookville, Sparta, McMinnville, Cowan*, and *Winchester*, is based on the St. Louis Limestone. *Smithville, Manchester*, and *Tullahoma* are near the western border of this belt. In the counties of Robertson, Montgomery, and Stewart, north of the Cumberland river and contiguous to the Kentucky line, is another large section, including much excellent land, which is based on the same rocks. Within this are the towns of *Springfield, Clarksville*, and *Dover*. Other towns located on the St. Louis Limestone are *LaFayette, Charlotte, Waverly, Vernon, Newberg, Waynesboro*, and *Lawrenceburg*.

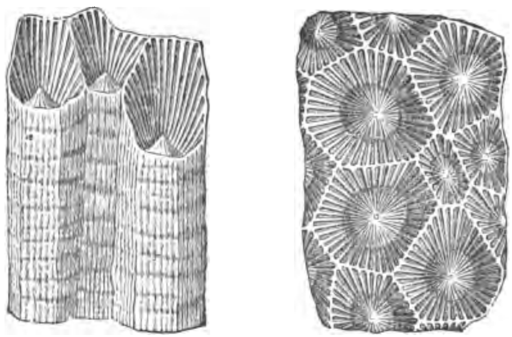
353. Wherever this formation underlies the surface, it is common to see porous flinty masses and more or less angular gravel, with here and there fragments of the large coral referred to, scattered over the ground or mixed with the red soil. Such regions also are remarkable for "sink-holes," underground streams, and caves.

354. Fossils abound in these rocks, and conspicu-

ous among them is the large coral. This bears the long name of *Lithostrotion canadense.* In Fig. 40 an end and side view of a piece of the coral are presented.

355. In East Tennessee the St. Louis limestone and the Barren Group are considered together as one formation. In both Middle and East Tennessee the two members are sometimes included under one name —the *Siliceous Group.*

Fig. 40.

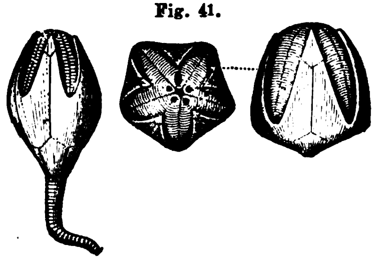


356. (3.) **The Mountain Limestone.**—Resting upon the Coral or St. Louis Limestone, and forming the base of the Cumberland Table-land, is the division known as the *Mountain Limestone.* Its layers outcrop on the slopes of the Table-land on all sides. The long tunnel on the Nashville and Chattanooga railroad is cut through this limestone, and the Sewanee railroad, in ascending the mountain, presents a fine section of its layers. The group includes a few beds of shale, one of which, near the top, is brown or reddish, and another pale green. In the southern

part of the State the entire formation is 700 feet thick, but near the Kentucky line it is reduced to about 400.

357. The mountain limestone is well filled with fossils, among which the remains of fishes, especially teeth, are not rare. In Fig. 41 two kinds of Crinoids are represented, which are frequently found in these rocks, and are sometimes thought to be "petrified hickory nuts." They are the remains of animals, however, and not nuts.

Fig. 41.



Crinoids.—Pentremites pyriformis; 2, 3. Pentremites Godonii.

358. Several belts or strips of the mountain limestone occur, with the Barren Group and the Black Shale, in the Valley of East Tennessee at considerable distances from the Table-land. They are found severally on Newman's ridge, east of Sneedville, east of Clinch Mountain, east of White Oak Mountain, and at Montvale Springs, in front of Chilhowee Mountain. At the base of the latter mountain, and running near the springs, is a tremendous fault or displacement of the formations (paragraph 182, p. 82), by which strata once 10,000 feet apart, in a vertical line, are brought right together. On one side of the fault is the top part of the Ocoee Conglomerate, and on the other, the Mountain Limestone.

359. (4.) **The Coal Measures.**—In this exist the beds of coal. It is a formation or series of interstratified sandstones, conglomerates, shales, and coal-

beds. The Coal Measures form the cap or top part of the Cumberland Table-land, and have the same horizontal extent, equal to 5,100 square miles.

360. The following section of the strata in the vicinity of the Sewanee Coal Mines, or Tracy City, will give a good idea of the character and alternation of the rocks of the formation. The lowest beds outcrop just above the Mountain Limestone in a deep "gulf" about two miles south of Tracy City, and the section includes all the strata in succession from these to the highest points on top of the Table-land near the mines. It commences with the lowest and ascends:

Lower Measures.	(1)	Shale and sandstone	40 feet.
	(2)	*Coal* of variable thickness	1 to 3 "
	(3)	Hard sandstone, often shale	78 "
	(4)	Sandy shale	22 "
	(5)	Shale, with a few inches of hard clay at top	8 "
	(6)	*Coal*, outcrop from	½ to 1½ "
	(7)	Sandstone	65 "
	(8)	Shale, with clay at top	10 "
	(9)	*Coal*, outcrop from	½ to 1 foot.
	(10)	CONGLOMERATE	70 feet.
Upper Measures.	(11)	Sandstone	17 "
	(12)	Shale	3 "
	(13)	*Coal*, outcrop	1 foot.
	(14)	Shale, some of sandy	33 feet.
	(15)	*Coal*, worked at the Sewanee mines	3 to 7 "
	(16)	Shale, more or less sandy, sometimes sandstone	45 "
	(17)	Sandstone	86 "
	(18)	Sandy shale	25 "
	(19)	Clayey shale	1 foot.
	(20)	*Coal*, outcrop	½ "
	(21)	Shale	23 feet.
	(22)	*Coal*, a few inches	
	(23)	Sandstone and conglomerate, at the top	50 feet.

361. The *conglomerate*, No. 10 of the section, must be especially noticed, as it divides the coal series into two members, the *Lower Measures* and the *Upper Measures*. It is also the top or surface stratum of much of

the Table-land, especially near its borders, and is the principal one of the hard rocks (there called sandstones) mentioned in paragraph 194, page 88. The cliff-edges of the Table-land are most generally this rock. It is often a sandstone, but frequently contains small white and rounded pebbles of quartz, whence the name conglomerate.

Fig. 42.

362. The *Lower Measures*, capped by the conglomerate, are co-extensive with the Table-land, and supply coal at very many points around its borders. The *Upper Measures* are more limited in horizontal

extent. They exist in ridges, or plateau-patches, of greater or less area, resting upon the conglomerate (ridges and tables on the Table-land), and of moderate height, but sufficient to carry one or two beds of good coal.

363. In the north-eastern part of the Table-land, however, in parts of Morgan, Anderson, Scott, Campbell, and Claiborne counties, the Upper Measures become of great thickness, more than 2,000 feet, forming really mountains on the Table-land, and including not less than sixteen seams of coal, many of which are thick enough for mining. Further details of the coal and coal beds will be given in Part V.

364. Coal has been formed, as stated on page 112, from beds of vegetable matter. The shales both above and below the coal seams often contain the impressions of leaves, among which occur also remains of fruits, branches, and even trunks of trees, the kinds of which, together with some of the kinds of animals living when the plants grew, are mentioned in the paragraph just referred to. In Fig. 42, on the opposite page, are representations of leaves of ferns found in the coal shales.

365. The towns located upon the Coal Measures, and of course upon the Table-land, are Huntsville, Jamestown, Montgomery, Wartburg, Crossville, Spencer, Altamont, and Tracy City.

366. Minerals of the Carboniferous Formation.—The most important of these is *coal.* Nodules of the iron-ore known as *clay iron-stone* are found in the shales of the Coal Measures, also large ledges of siliceous brown hematite. *Barite, Quartz, Gypsum, Sulphur, Epsom Salts, Nitro-calcite* (the latter two in caves), and *Lead ore,* are found in the limestones

of the Formation, but are nowhere of much economic interest. *Petroleum* has been found in considerable quantity in Overton county.

367. The Permian Period.—On page 108 this is given as one of the periods of the carboniferous. Its rocks, which are limestone, sandstones, shales, beds of gypsum, etc., do not exist in Tennessee. In Kansas, west of the Mississippi river, they have considerable development. In Europe it is an important formation.

CHAPTER XII.

The Mesozoic and Cenozoic Formations of Tennessee.

368. It remains to consider the formations of the State included in Mesozoic and Cenozoic times. These are, in the main, confined to West Tennessee, and embrace strata very different in appearance from those we have been studying. In the place of hard sandstones, limestones, and shales, we have now beds of sand, clays, marls, etc., that have never been hardened, with some local exceptions, into what are popularly called *rocks* (paragraph 119, pp. 59, 60). These unconsolidated strata are the only Tennessee representatives of the two great geological times mentioned.

369. *Mesozoic Time* was a mediæval era in geological history, a middle era so far as the kinds of animals and plants were concerned. During this Time many of the old Paleozoic species, like the Trilobites, no longer existed; while, on the other hand, new species appeared, such as the first of Birds and Mammals, and among plants the first of Palms and Angiosperms, like the Oaks, Maples, Walnuts, etc. (p. 103). The Reptiles were the most characteristic animals of the era; it was the Age of Reptiles, the only age included in the time (pp. 109, 113).

370. *Cenozoic Time*, or the Time of recent Life, is the modern era in geology. It includes two ages, the Age of Mammals (p. 113) and the Age of Man (p. 114). At the first its animals and plants, if not quite the same in species, belonged very generally to the families, and often to the genera with which we are familiar. Every thing wore a modern aspect. Toward the last of the Time the life of the present day was introduced.

371. On previous pages (60, 114) it is stated that the Gulf of Mexico once reached up as far as the mouth of the Ohio, and that from these waters the strata peculiar to West Tennessee were deposited. The part of the *old shore* of the Gulf that was in Tennessee is easily traced out. It extends from Mississippi to Kentucky in a northerly and southerly direction, coinciding with the Tennessee river through a part of Hardin county, but elsewhere a few miles west of that stream. The towns of *Camden* and *Decaturville* are nearly or quite upon it. Along this line the older strata (the limestones and other rocks of Middle Tennessee) and the strata peculiar to West Tennessee come in contact. The first are abruptly beveled off to an unknown depth, presenting their edges to the west; the latter overlap unconformably the beveled and sloping edges of the first.

On the map (p. 116) the old shore coincides with the line marking the eastern boundary of the area V (Cretaceous), and in the section on the next page the beveled edges are seen with the formation V resting upon them. The inclination of the slope of the edges and the dip of V are much too great as represented in the section. They have been purposely exaggerated.

372. The formations confined to West Tennessee are the *Cretaceous* and the *Tertiary* (pp. 119, 120). The *Quarternary,* while having its greatest development in this part of the State, is also represented by superficial deposits in the other parts. The Cretaceous is included in Mesozoic Time; both the others are Cenozoic.

373. In the section on page 109 two Mesozoic formations are given, the *Triassic* and the *Jurassic,* which are not found in Tennessee. Rocks of these formations, mostly red sandstones, occur in long narrow strips, running parallel with the Atlantic coast in the eastern border states from Maine to North Carolina. Many trap dikes are met with in the sandstones of these strips. These are referred to on page 69 as making ridges in the Atlantic states, including the Palisades of the Hudson. Rocks of the Triassic and Jurassic age also occur in the west between the Mississippi river and the summit of the Rocky mountains, and beyond this summit on the Pacific slope. In the west they are sandstones, marls, limestones, with which are beds of gypsum. In Europe the formations are well developed. The word *Triassic* means *triple,* and refers to the fact that in Germany the formation has three divisions. The word *Jurassic* is derived from the name of the mountains called *Jura,* in which the Jurassic formation exists. The cut on page 77 represents Jura strata and mountains.

V.—The Cretaceous Formation.

374. The general character of the Cretaceous formation in Tennessee is given in paragraph 267, on page

119. It has three divisions, the limits of which, as well as those of the formation itself, are given approximately. The divisions are as follows:

(a.) *Coffee Sand*—A heavy bed of laminated sand containing clayey leaves and layers; 200 feet thick.

(b.) *Rotten Limestone, or Green Sand*—A stratum made up of sand, clayey and calcareous matter; it contains green grains and fossil shells in profusion; 350 feet.

(c.) *Ripley Group*—Much like the coffee sand; perhaps 400 feet thick.

375. (*a.*) **The Coffee Sand.**—This is the lowest of the Cretaceous beds outcropping in West Tennessee. It is a group of stratified sands, usually containing scales of mica. Interstratified more or less with these sands are thin, often paper-like layers of dark clay, the clayey layers sometimes predominating. Occasionally beds of laminated or shaly clay of considerable thickness—from one to twenty feet or more—are met with in the series. The group contains in abundance woody fragments and leaves, converted more or less into the half-formed, imperfect kind of coal called *lignite* (p. 178).

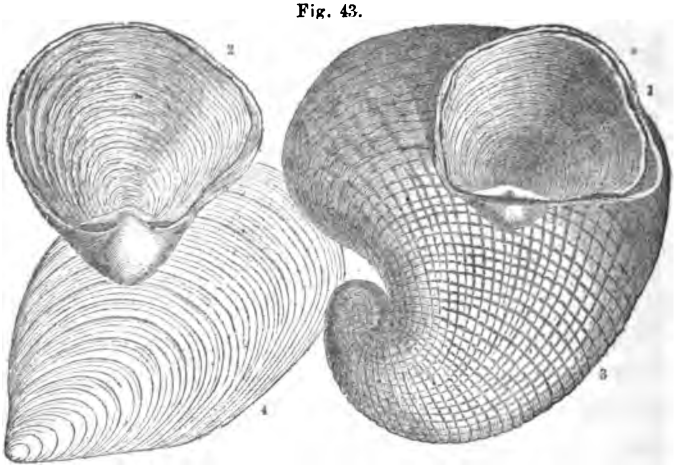
376. The layers of the Coffee Sand are well exposed in the bluffs on the Tennessee river, in Hardin county, at *Coffee*, *Crump's*, and *Pittsburgh* landings. From the first of these the formation gets its name. The bluffs are made up of these layers, with the exception of a covering of gravel on top of them belonging to the *Orange Sand* formation to be described. They are seen also at *Scott's Hill*, on the road from Lexington to Clifton. Decaturville is in part upon their outcropping edges.

The area of outcrop of the Coffee Sand is a narrow belt including

chiefly the western parts of Decatur and Hardin counties. Its layers are very generally concealed by the superficial gravel and sand of the Orange Sand group referred to.

377. (*b.*) **The Rotten Limestone (Green Sand).**—This formation is called *Rotten Limestone* because it has the appearance, especially in Alabama and Mississippi, in which states it also occurs, of a soft chalky limestone. Its mass consists of fine quartzose sand mixed with clay and much calcareous matter. The mass contains

Fig. 43.

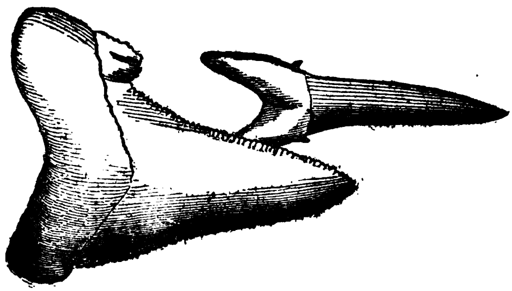


Mollusks.—1. Gryphæa vesicularis; 2. Exogyra costata; 3. Gryphæa Pitcheri; 4. Inoceramus problematicus.

also the *green grains* of a mineral called *glauconite,* and layers rich in this may be used as a fertilizer. These grains are soft, and were they black would closely resemble the grains of gun-powder. They give a greenish color to the stratum, and hence the name, *Green Sand.*

378. The Rotten Limestone contains in abundance fossil shells of many varieties, some of which are of large size. Among them are great fossil oyster shells, which have been abundant enough at some localities to gather and burn into lime. In Fig. 43, on opposite page, are reduced representations of some of the large shells. Nos. 1, 2, and 3 are oyster shells, the first two of which are found at many localities. They are, with other shells and fossils, among which are sharks' teeth (Fig. 44), very conspicuous on the "*bald hills*" or "*bald places*" of the counties in which the Rotten Limestone outcrops. These are marly places, often bare, or with but little vegetation.

Fig. 44.



Sharks' Teeth.

379. This formation is the northern extension of the Rotten Limestone of Alabama and Mississippi. It lies in a belt extending through the eastern parts of McNairy and Henderson counties, and the extreme western parts of Hardin and Decatur. Its maximum thickness, 350 feet, is in McNairy.

380. (*c.*) **The Ripley Group.**—This division, like the Coffee Sand, is a series of laminated sands containg thin clayey layers, and occasionally beds of shaly clay. In Hardeman county it includes a bed of fossiliferous impure limestone, from two to six feet in thickness, and a bed of clayey calcareous sand, containing green grains and shells.

381. The outcrop of the Ripley Group, often, however, concealed by the Orange Sand, occupies a belt of surface extending from Kentucky to Mississippi through the eastern parts of Henry and Carroll counties, the western part of Benton, the middle of Henderson and McNairy, and the south-eastern part of Hardeman. Camden is at its eastern edge; Lexington and Purdy are upon it, and Middleton near its western edge. Its limits are provisional, and may be modified hereafter. The belt includes the Tennessee ridge (p. 37). Much of the country is high and broken. With the belts of the Coffee Sand and the Rotten Limestone it makes up the area V on the map.

VI.—The Tertiary Formation.

382. The student will refer to page 120 for a brief notice of the Tennessee Tertiary, and to pages 113 and 114 for the character of the Tertiary in general. In Tennessee we have, as may be seen in the section on page 109, but two divisions, which are as follows:

(*a.*) *The Flatwoods Sand*, or *Group*.
(*b.*) *The La Grange Sand*, or *Group*.

383. Both of these belong to the lowest Tertiary, or to the *Eocene*, one of the *three* members into which geologists have divided the Tertiary, the other two members being the *Miocene* and *Pliocene*. The name *Eocene* does not appear in the section. The American periods called *Lignitic* and *Alabama*, as well as the Tennessee divisions, are Eocene. These lower Tertiary beds are found in the southern states, and in the great regions west of the Mississippi river. Miocene and Pliocene beds occur in the same states and regions, and also in the Atlantic states.

384. (*a.*) **The Flatwoods Sand, or Group.**—The name *Flatwoods* was given to this group by the Mississippi geologists. In Tennessee the formation has, perhaps, a thickness of 200 or 300 feet. In the character of

its layers it does not differ much from the Ripley and Coffee group, except in containing more laminated or shaly clay. On Porter's Creek, in the southern part of Hardeman county, a bed of shaly clay ("soapstone") occurs in the series which has a thickness of 100 feet.

385. Along the Memphis and Charleston Railroad the belt of surface occupied by the group is about eight miles wide. From this region the belt, becoming narrower, extends to the Kentucky line. Like the Ripley Group, its limits are provisional. Paris and Huntingdon are near its western limits. Its belt of outcrop is a narrow strip lying next west of the line on the map separating the areas V and VI. It does not reach Jackson.

386. (*b.*) **The La Grange Sand, or Group.**—This is the formation of more than a third of the area of West Tennessee. It occupies a belt forty miles wide, which extends in a north-easterly direction from Mississippi to Kentucky, and is the central portion of this division of the State. Like the Coffee Sand and other formations described, it is in general a mass of grayish sand, thinly interstratified, containing thin clayey layers, often dark, with vegetable matter. Beds of lignite are, at some points, met with. When weathered, or near the surface, the sands are usually yellow, red, or orange. The series includes also beds of white and variegated clays. The thickness is unknown, and may be as much as 600 feet. Many fine farming regions and cotton lands lie within the area of the group.

387. A good section of its layers is exposed at *La Grange*. In the counties of Shelby, Tipton, Lauderdale, Dyer and Obion, east of the Mississippi bluffs (p. 37), it is covered by a belt of Quarternary beds. In the bluffs, however, it outcrops under the gravel of the Orange Sand, and interesting sections are exposed at numerous points, as at *Randolph* and *Fulton* on the Mississippi river. In most of the section of the bluffs beds of lignite occur. A section may be seen at Raleigh, on Wolf river, in

Fig. 45.

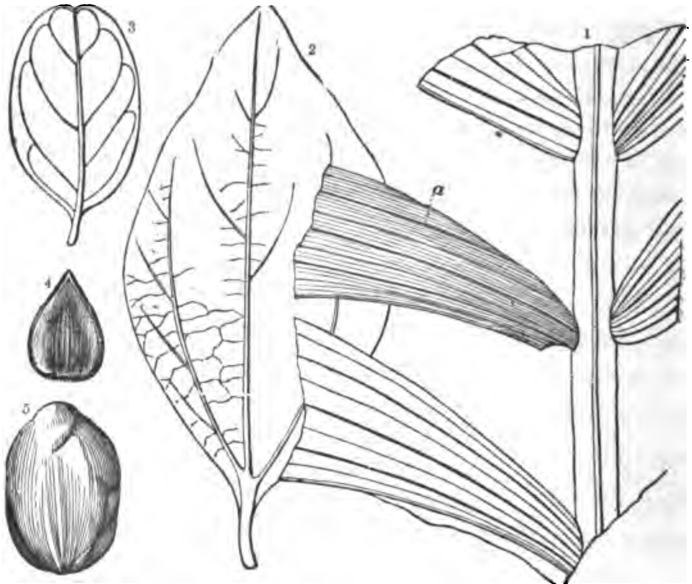


Fig. 1. Quercus (Oak) myrtifolia; 2. Cinnamomum (Cinnamon) Mississippiense; 3. Calamopsis (Palm) Danæ; 4. Fagus ferruginea (a Beech nut); 5. Carpolithes irregularis (also a nut).

which is a bed of lignite. At Memphis the formation outcrops at a low level below the gravel.

388. Impressions of leaves are frequently met with in this formation. Many of the leaves do not belong to species now existing, and many to genera which only grow in tropical regions. Some of the vegetable remains are represented in Fig. 45, on this page. No. 1, an oak leaf, and No. 4, a beech nut, were found near Somerville, Fayette county.

The following county towns are within the limits of the La Grange group: *Dresden*, *Paris*, *Huntingdon* (the two last near its eastern limit), *Trenton*, *Brownsville*, *Alamo*, *Jackson*, *Somerville*, and *Bolivar*.

VII.—The Quarternary Formation.

389. In this are included the superficial deposits of the State. A brief description of the group in general is given on page 120. See further on pages 114 and 115. It corresponds to the *Age of Man*, which is divided into three periods, the *Glacial*, *Champlain*, and *Recent*. The student will review what is stated on the pages referred to.

390. The Tennessee divisions of the Quarternary are as follows:

(*a.*) The *Orange Sand.*
(*b.*) The *Bluff Loam.*
(*c.*) The *Alluvium.*

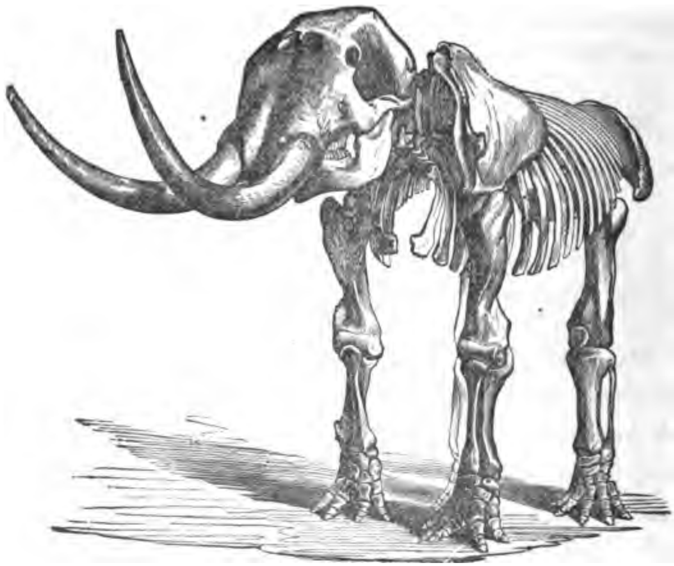
391. The Orange Sand.—This is a wide-spreading, superficial formation of gravel and sands, of orange, reddish and variegated hues. Its greatest development is in West Tennessee; it is also met with in other parts of State. Some of it is the southern extension of the *Drift*, and all of it may be included under this name (paragraph 255). In some regions, especially in West Tennessee, it entirely conceals, with its coating of sand or gravel, or both, the outcrops of what may be called the regular formations. The Cretaceous and Tertiary beds are very often covered by it.

392. In the Mississippi bluffs it outcrops *below* the Bluff Loam, and next *above* the La Grange Group. At Memphis it lies at a low level, and has supplied much sand for building purposes. Most of the isolated

blocks of sandstone, which curiously cap certain high points in West Tennessee, as at Millstone, in Tipton county, belong to the Orange Sand.

The superficial gravel beds of the uplands of the Western Valley, the water-worn gravel of the Western Iron-ore region (perhaps also the ore banks themselves), and the gravel found so commonly in the vicinity of the East Tennessee rivers, are all referable to this group.

Fig. 46.



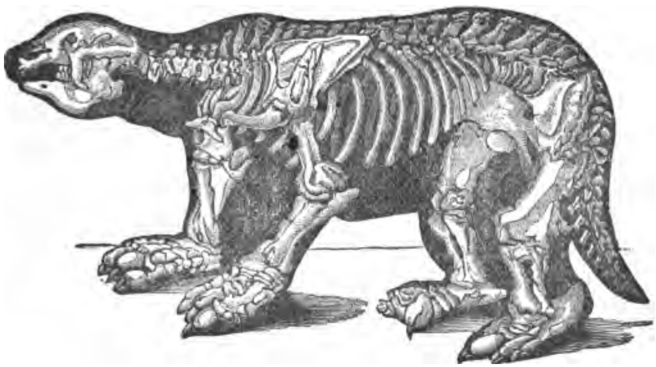
393 (*b*.) **The Bluff Loam.** — This lies upon the Orange Sand, and is, therefore, of later date. It is a superficial formation, and makes comparatively a narrow belt of surface, which extends from Mississippi to Kentucky, and includes most of the uplands of Shelby, Tipton, Lauderdale, Dyer, and Obion. This belt is the part of the area VII on the map, hav-

ing sloping lines. It is the topmost stratum of the Mississippi bluffs.

394. The formation consists of fine siliceous loam, more or less calcareous, and usually of a light ashen, yellowish or buff color. It contains land and fresh water shells, and frequently calcareous nodules, or curiously shaped stones. In thickness it ranges from a few feet to one hundred.

395. The soil of the Bluff Loam is generally of excellent quality, upon which flourish forests noted for trees of very large size. *Memphis, Raleigh, Covington, Ripley, Dyersburg, Troy,* and *Union City,* are located upon the formation.

Fig. 47.



The Loam belongs to the *Champlain* period. Some of the animals mentioned on page 115 have been found in it. Among them are bones of the *Mastodon* (M. Americanus), the skeleton of which is represented in Fig. 46, on opposite page. Remains of this animal occur also in the later Alluvial deposits at localities in all three divisions of the State. The name of another animal, the remains of which have been found, is *Megalonyx.* This was of the sloth kind, and allied to the great *Megatherium,*

which had a length of 18 feet. It is represented in Fig. 47. The bones of this monster are found in South America.

396. (*c*.) **The Alluvium.**—The alluvial bottoms of all the rivers in the State are properly included in this division. They are the most recent deposits, and consist of the washings brought down by the rains and waters from the uplands. The most important alluvial area is that of the Mississippi Bottoms (p. 38). It lies between the bluffs and the Mississippi river, and is the part of VII on the map having v-shaped markings. Lake county, in the north-western corner of the State, is wholly within this area. The rivers generally present alluvial tracts of unsurpassed fertility.

PART V.

ECONOMIC GEOLOGY.

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397. Economic Geology treats of substances that bear directly on the arts, industries, and progress of civilized life. A generally diffused knowledge of the quantity, quality, and localities of whatever contribute to such results cannot fail to exercise a beneficial influence upon the material interests and prosperity of the State.

The mineral map on page 173 will designate the locality of all the valuable minerals in the State. The student would do well to study this map until he is familiar with the coal area, the iron belts, the region of copper, zinc, marble, and other substances which are treated of in this Part.

CHAPTER XIII.

Coal Area, Coal, and Coal Mines.

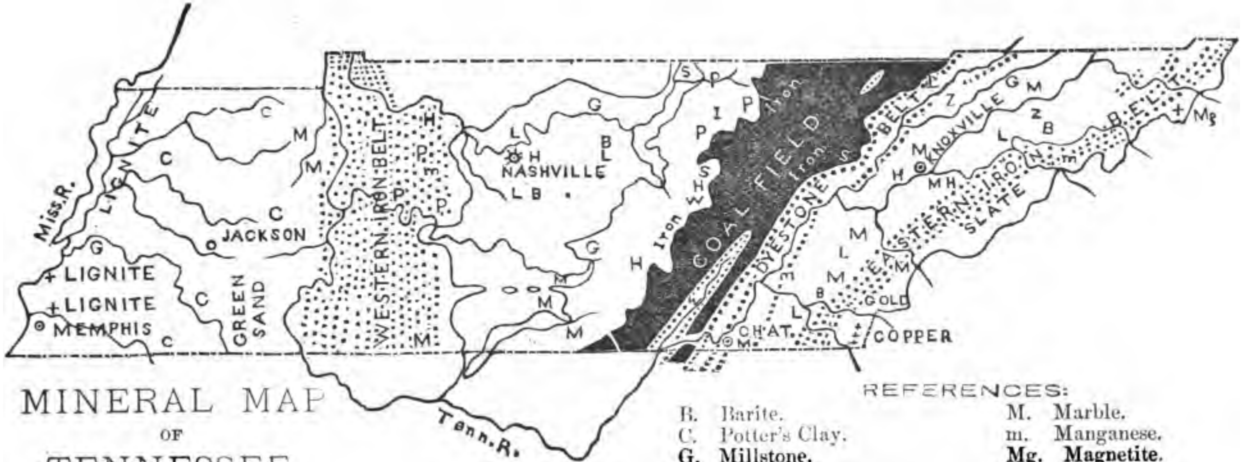
I.—Coal Area, and Coal.

398. Though classed as a mineral, coal is of vegetable origin. Next to iron it is the most important of all our mineral products. The coal region of Tennessee is a part of the great Appalachian coal-field which extends in a north-easterly and south-westerly direction for a distançe of 875 miles through the western

part of Pennsylvania, the eastern part of Ohio, the western corner of Maryland, embracing nearly all of West Virginia, and the eastern part of Kentucky, crossing Tennessee and ending near Tuscaloosa, Alabama. It embraces an area of 80,000 square miles, of which 60,000 will furnish available coal. This is ten times the area of the productive coal-fields of Great Britain, and eight times as great as all the explored coal-fields of the remainder of Europe.

399. Of this coal-field Tennessee has about 5,100 square miles. It includes the counties of Morgan, Scott, and Cumberland; the greater parts of Fentress, Van Buren, Bledsoe, Grundy, Sequatchee, and Marion; considerable portions of Claiborne, Campbell, Anderson, Rhea, Roane, Overton, Hamilton, Putnam, White, and Franklin, and small portions of Warren and Coffee: The area of coal, in other words, embraces the whole of the Cumberland Table-land, the third natural division of the State. Its area is represented on the map on page 173.

400. We have already (p. 32) spoken of the leading physical features of this division. The student will remember that the edges of the table-land are made prominent and striking by a bold cliff, resembling a huge massive wall running along near the top of the mountain.. This cliff is the outcrop of a conglomerate rock, averaging seventy feet in thickness. It divides the coal-field horizontally into two parts, called the *Lower* and *Upper Coal Measures*.



MINERAL MAP
OF
TENNESSEE.

REFERENCES:

B. Barite.
C. Potter's Clay.
G. Millstone.
H. Hydraulic Limestone.
I. Iron.
L. Lead.
M. Marble.
m. Manganese.
Mg. Magnetite.
P. Petroleum.
S. Salt.
W. Whetstone.
Z Zinc

By *Coal Measures* is meant, as we have seen, a series of strata in which the seams of coal occur. The seams of coal form layers (not veins) like the layers of limestone and other sedimentary rocks. Beneath all the seams are beds of bluish or gray clay which, in some cases, were the soils upon which the plants grew that supplied the material for the formation of the coal. Above the coal are usually bluish or black shales which split easily. They contain beautiful impressions of coal-plants, the study of which affords a pleasing recreation to geological students (p. 166).

401. The *Lower Coal Measures* rest immediately upon the massive mountain limestone which extends one-third, and sometimes two-thirds, the way up to the cliff-forming conglomerate. Immediately upon the limestone rest strata of shales and sandstones, with three, and rarely four, seams of coal. The coal-seams of the Lower Measures are not uniform in thickness, but variable and irregular, sometimes thinning out to a few inches, and then again swelling out into masses or pockets six or seven, and even twelve, feet thick. The coal, however, is usually of excellent quality.

402. The *Upper Coal Measures* make hills, ridges and even mountains, resting upon the main conglomerate. In these sometimes as many as eight workable seams of coal occur, generally, however, only two or three.

A seam of coal is workable when it is over two feet thick.

The seams of the Upper Measures are more uniform in thickness, and can be relied upon with more certainty than those of the Lower Measures.

403. Along the eastern edge of the coal-field, both in

the Upper and Lower Measures, the seams are thrown up with the other strata into folds or flexures. These flexures are seen in the coal at the Rockwood and a few other mines. In connection with these folds or flexures faults occur which displace the strata, and occasionally interfere with mining.

The Upper Measures in the western counties are by no means as thick as in the north-western part of the coal-field, but they are often thick enough to give two or more seams of good coal.

404. Deep ravines are cut into the coal-field, and these are of great value in opening the coal, making it accessible and easy to mine. The Sewanee coal mines have this advantage, as well as a large scope of country lying to the east and north. Fully one-fourth of this region contains the Upper Measures.

In parts of Anderson and Claiborne counties the main conglomerate sinks down to the level of the valley, nevertheless the mountains here are much higher than in any other part of the coal-field, and the seams of coal are more numerous.

405. Quantity of Coal.—It is estimated that a coal-bed one foot thick will yield 1,000,000 tons, or 25,000,000 bushels, to the square mile. The coal-seams of Tennessee, all placed together, would make a bed eight feet thick all over the coal-field. This would give 8,000,000 tons to the square mile, or 40,000,000,000 tons for the State. The present rate of consumption is about 400,000 tons annually. At this

rate it would take 100,000 years to exhaust our coal supply.

406. Quality of Tennessee Coal.—There are two leading varieties of coal, *Bituminous* and *Anthracite*.

Bituminous coal yields, when heated, a mineral tar, and also an inflammable gas. This mineral tar burns like bitumen, with a yellow, smoky flame, giving out the same odor, and hence the name. There is no bitumen in the coal, but bituminous substances are formed by the action of heat, just as the gas is made which lights our cities.

407. Anthracite has been derived from bituminous coal by the action of subterranean heat under pressure. In this way it has lost most of the elements which form by heat its bituminous or flame-making substances. It is, indeed, a sort of *native coke*.

408. All the coals of Tennessee belong to the bituminous kind. These are variable in their yield of bituminous substances. Those coals yielding the largest quantity are valuable for making gas.

Bituminous coals may be classified into caking, non-caking, and cannel coal.

(*a*.) *Caking* coal, which softens and becomes a pasty or semi-liquid mass in the fire, from which bubbles of gas escape. When the volatile products have been drawn off in partially closed ovens, the fritted mass which remains is called *coke*. This is used in the manufacture of iron.

(*b*.) *Non-caking* coal, which does not soften under heat. Under this may be included *cherry* or *soft* coal, which ignites readily and burns rapidly; *splint* or *hard* coal, which ignites and burns less freely. *Free-burning* coals are those which do not cake, while the caking coals are sometimes called *binding coals*.

(*c*.) *Cannel* coal, or *Parrot* coal, which is compact, even in texture, and of a dull black color, and has not the banded structure seen in other

coals. Some varieties, when ignited, burn like a candle, from which it takes its name. It yields a large proportion of bituminous oil, which is sometimes distilled out of it and used as a coal oil, or burning fluid.

409. The most valuable constituent of coal is carbon, and coals are rich or poor in proportion to the amount of carbon they contain, setting aside impurities. Twenty-two samples of Tennessee coal, taken from various mines, show an average of 64.6 of carbon; 30.61 per cent. of volatile matter, and 4.8 of ash.

Iron pyrite or pyrites, often called sulphur, and slate, injure the quality of coal. The coals of Tennessee are remarkably free from such impurities.

II.—Coal Mines and Coal Product.

410. Coal Mines.—Coal is mined at many places in the State. The principal points are the Sewanee Mines in Grundy county; the Ætna, Vulcan, and Battle Creek Mines, in Marion; the Coal Creek Mines in Anderson, and the Soddy and Sale Creek Mines on the Tennessee river, in Hamilton county. About seven hundred men are kept actively employed in these mines, and the coal product is distributed by railways to various markets in and out of the State.

The coal taken out at other places is used in the manufacture of iron, or for local purposes.

411. Coal Product.—In 1854 the amount of coal mined in the State was 8,836 tons. Since that period the production has greatly increased. In 1875 the quantity raised was about 400,000 tons, worth in the market

$1,200,000. Many new mines are now opening, and foreign capital is seeking employment in the coal region of Tennessee, which must, in time, be the theatre of immense wealth, and of ceaseless industrial activity. The building of an important railway through the coal-field will multiply the present production many fold.

412. Brown Coal, or Lignite.—Lignite (from the Latin for wood) is an impure, half-formed coal found in the more recent formations. In it the woody structure is not destroyed, and may be easily seen with the naked eye. It occupies a place midway between the true coal and a mass of dead vegetable matter. In appearance it sometimes looks like true coal, but has rarely the lustre and compactness of that mineral. Sometimes it is of a brown color, spongy and light.

413. Lignite does not take fire readily, but when ignited burns like rotten wood, and gives out the peculiar odor of burnt vegetable matter.

Extensive beds are found in the counties that overlook the Mississippi bottoms, especially in Obion, Dyer, Lauderdale, Tipton, and Shelby. A bed also occurs in Johnson county.

The seams often overlie each other, with beds of clay and sand interstratified, which correspond to the shales and sandstones of the Coal Measures. They vary in thickness from a few inches to four or five feet. These beds do not spread out very far, and appear to have been formed from accumulations of

drift, or from the former growth of swamps. Some varieties of lignite are hard, and when polished present a brilliant black surface. Such constitute the *jet* used in jewelry.

414. At Raleigh, in Shelby county, a mine of lignite was once opened and worked, and the lignite used as a fuel, but it did not prove satisfactory. When used as such it must be mined in summer and thoroughly dried, and even then it is inferior to wood as a producer of heat.

415. The student should familiarize himself with this substance, its proper place in the formations, and its points of similarity and dissimilarity to true coal. It is often mistaken for genuine coal, and many fruitless adventures have resulted from ignorance in these particulars, and much valuable time and money lost.

416. Coal and Lignite each has its geological formation, and to one acquainted with the elements of geology, the one can never be mistaken for the other. In this one of the practical advantages arising from the study of geology may be seen. It serves as a check to wild schemes of speculation, and shows the folly of seeking for a substance in a formation in which it never occurs. In Tennessee the coal formation is distinctly marked, and outside of it true coal is not to be expected. It is only through the principles of geology that we can determine with certainty the absence of coal, and its probable presence in any given region; in other words, geology teaches us where to look for coal.

CHAPTER XIV.

Iron Ores and Iron Manufactures.

I.—Iron Ores.

417. Iron Belts.—The iron ores of Tennessee, as may be seen by referring to the mineral map on page 173, lie in four distinct belts:

I. The *Eastern Iron Belt*, extending in a north-easterly and south-westerly direction through the State, and lying at the base of the Unaka Range.

II. The *Dyestone Belt*, bordering the eastern base of the Cumberland Table-land, and spreading out laterally from ten to twenty miles into the Valley of East Tennessee, including also the Sequatchee and Elk Fork Valleys.

III. The *Cumberland Table-land*, in which the ores are of least importance. This belt corresponds to the coal region.

IV. The *Western Iron Belt*, lying mainly upon the Highland Rim west of the Central Basin, extending to the Tennessee River, and including the counties of Decatur and Benton beyond.

418. I. The Eastern Iron Belt.—This belt runs through the counties of Johnson and Sullivan, Carter, Washington, Unicoi, Greene, Cocke, Sevier, Blount, Monroe, McMinn, and Polk.

In this belt there are three classes of ores, viz.: *Limonite*, *hematite*, and *magnetite*. These ores may all

be recognized by the color of the powder obtained by pulverizing them: that of the limonite being *yellow;* of the hematite, *red;* and of the magnetite, *black.*

419. Of these *the limonite,* sometimes called *brown hematite,* is the most abundant, and is the same in composition as iron rust. When pure it yields nearly sixty per cent. of iron, the other ingredients being oxygen and water. It occurs in many forms, and from these forms the common names are taken. Thus we have *shot* or *pea* ore, *honey-comb ore, pipe ore* (like a bundle of *pipe* stems or rods adhering), *pot ore, needle ore, yellow ochre,* and *compact ore.* Limonite, as the name indicates (from the Greek word for meadow), is frequently found in bogs or marshes beautifully laminated, being a sedimentary deposit from the decomposition of other ores. Thus we have the *bog ore.*

420. In the Eastern Belt the limonite occurs mainly in the compact form, often in nests, and in shapeless masses. It is not found in the highest mountain ridges, but in spurs and foot hills, mingled with red and yellow clays, and cherty masses. Some good banks are found in valleys and coves. In Greene county it is associated with a mineral known as *oxide of manganese,* from which the *spiegeleisen* (pronounced spe-gel-i′-sen) or *looking-glass iron* is made. This is employed in the manufacture of *Bessemer steel,* from which steel railroad bars are produced

421. *The Hematite* (signifying bloodstone) differs from the limonite, theoretically, only in having no water in its composition. Practically, however, this ore always contains from 1 to 4 per cent. of water. When the limonite is heated sufficiently to expel the water, it becomes the red oxide or hematite. Free from impurities, it yields about 70 per cent. of iron. One variety of this ore, when sufficiently soft, is used for dyeing, and hence comes the name, *Dyestone.*

422. This ore occurs at many localities in the Eastern Belt. In the valley of Stoney creek, in Carter county, it is found in massive layers from one to two feet in thickness, regularly bedded, and rests upon a thin bed of conglomerate, holding small pebbles. It is found in Sullivan county, in a vein-like mass, nearly vertical; in Monroe and Cocke counties, in compact masses, and on Cross mountain in angular nodules. South-west of Athens a very large bed of hematite occurs in the Lower Silurian. A similar ore of the same age outcrops in Loudon county.

423. Magnetite.—This is the richest of all the iron ores, yielding, when pure, about 72 per cent. of excellent iron, which is highly esteemed for the manufacture of steel. The ore takes its name from its magnetic properties, being attractable by the magnet. It occurs in the metamorphic formations in compact, heavy masses of a brittle texture, and an iron black color, associated with hornblende and pyroxene. In the state of Tennessee it is found in workable quantities only in the spurs that run down into Crab Orchard Valley in Carter county, where it has been worked in forges for many years. Much of the ore

in this place is the true loadstone, attracting iron filings like a magnet, and conferring the same property as the steel. Very large deposits of this ore, extending for twenty miles, lie just beyond the Tennessee line in North Carolina, and which, in time, must be worked by the coal of Tennessee. Its average yield is over 60 per cent. of metallic iron.

424. II. **The Dyestone Belt.**—This belt embraces three or four lines of ore nearly parallel. Beginning at the south, the most important enters the State near Chattanooga, running continuously along the eastern base of the Cumberland Table-land, and passing into Virginia at Cumberland Gap. The other lines are more interrupted by breaks or gaps. One of these lies on the west in Sequatchee Valley.

425. The ore of this belt is a variety of hematite, yielding usually about 56 per cent., but when pure about 70 per cent. of iron. It is called *dyestone* because it is often used for dyeing purposes. It is also called *fossil ore*, from the great abundance of fossils it contains. These fossils are usually casts of crinoidal buttons, small corals, shells, and fragments of trilobites. The ore also abounds in small, flattened *oolitic* bodies, and for this reason is sometimes called *oolitic ore*. When freshly quarried it has a bright reddish color, sometimes nearly scarlet. At some places it has a royal purple color. It is often hard enough to be quarried in blocks; again it is soft, and easily crushed. Some of it presents the ap-

pearance of a specular ore having a highly splendent lustre.

426. Unlike the limonite, it is not found in banks or "nests," but in regular strata of variable thickness, ranging from six feet down to a few inches. Its most usual thickness is about three feet. The stratum skirting the base of the Cumberland Table-land dips westwardly under the mountain, while that in Sequatchee Valley dips eastwardly, making it highly probable that the stratum is continuous under Walden's Ridge, the arm of the Table-land that separates Sequatchee Valley from the Valley of East Tennessee.

427. Excellent deposits of this ore are found on the Tennessee River in the Half Moon Island region, both on the island and on the mainland, in Meigs county. It is easily carried by water to furnaces at Chattanooga and other points. It is also found in abundance in White Oak mountain, in James county.

The layers of the dyestone are attended with red and greenish shales, and thin, even-bedded sandstones. These, with the ore, make up the Dyestone formation, a part of the Niagara geological series (page 143). Two other formations, the Black Shale and the Siliceous Group, are associated with the Dyestone group in the same ridges, the ore being the lowest.

428. The counties containing this ore in workable quantities are Hamilton, Bradley, James, McMinn, Meigs, Rhea, Roane, Anderson, Campbell, Union, Grainger, Claiborne, and Hancock; Marion, Sequatchee, and Bledsoe.

429 The Dyestone Belt offers great advantages for the cheap manufacture of iron. In many places coal, ore, limestone for flux, and sandstone for furnace hearths, are all found within a few hundred yards of one another, and near transportation. A railroad connecting Chattanooga with Cincinnati is also building parallel with the most important seam, and near it.

430. **The Belt of the Cumberland Table-land.**—The iron ores of this belt have never been used in the manufacture of iron, though the same character of ores is largely used in England, and in some of the states north. They are known as *clay iron stones* and *black band.* They occur in nodules, and sometimes in layers, in greater or less quantities, throughout the area of the coal formation. At one place near Sewanee there is a ledge three feet thick, extending for more than a mile. This, however, is a siliceous brown hematite. These ores rarely yield more than thirty per cent., usually not over twenty.

431. **The Western Iron Belt.**—This belt is fifty miles wide, and runs through the State from north to south, embracing an area of 5,400 square miles. (See map on page 173.) It also extends northward into Kentucky to the Ohio river. The following counties are included in the belt, viz.: Lawrence, Wayne, Hardin, Lewis, Perry, Hickman, Humphreys, Dickson, Houston, Montgomery, and Stewart, on the east side of the Tennessee river, and Benton and Decatur on the west. The geological formations of this region have been spoken of on pages 151, 152.

432. The different varieties of limonite are found

in this belt. The ore usually occurs in spurs or ridges, associated with cherty masses and gray and red clays. The lumps of ore are variable in size, and are disposed in no regular order in the banks.

The principal typical features of a bank may be thus noted:

1. A covering of clay and chert and rounded gravel four or five feet in thickness, which constitutes the "stripping."

2. Below this covering a bed of clay, flint, and sand, with ore.

3. The ore lying scattered at irregular intervals through this bed, sometimes in layers, with intermingled chert and clay; sometimes in "nests," and sometimes in large, irregularly shaped masses, several feet in thickness; again in lumps from the size of a walnut down to a grain of corn.

4. The course of the ore is marked by tortuous dark veins or seams winding through the banks in different directions, and sometimes swelling out into rounded or shapeless masses of varying thickness. These are the principal characteristics of every bank.

433. The *pot ore,* so usual in these banks, is a hollow concretion filled with water or decomposing chert. Occasionally one is found enclosing the coral (Lithostrotion canadense) represented on page 153.

The ridges or hills containing deposits of ore vary in height from fifty to three hundred feet or more. Deposits are sometimes, though rarely, met with in the valleys and river basins.

434. The best deposits yet discovered are those near the Cumberland and Tennessee rivers in Stewart county; in the south-western corner of Montgomery; on Barton's and other creeks in Dickson county; in a series of hills north and south of Centreville in Hickman county; on Chief's

creek in Lewis county; and on Shoal creek in the south-western part of Lawrence county. Numerous rich deposits are also met with in Decatur and Benton counties, a few miles from Tennessee river. All these localities may be regarded as *iron centres*, around which are grouped a series of hills and ridges abounding in limonite.

435. A fine powdery ore, though sometimes compact in layers, mostly hematite, occurs in several knobs not far from Clifton, in Wayne county, the only locality in the western belt where this red ore is found. This ore is valuable for making paint, being a deep Spanish brown. There are a few counties on the eastern side of the Highland Rim containing considerable quantities of ore, White, Putnam, and Warren having the largest deposits.

436. *Charcoal* is the only fuel used in the manufacture of iron in the eastern and western iron belts. About 130 bushels are consumed in the making of every ton of iron. Stone coal and coke are used in some of the furnaces of the Dyestone belt. Coke is coal with the bituminous or oily matter burnt out. About 80 bushels of coke are used in the production of a ton of iron. Stone coal was first used for making iron in Tennessee at Rockwood, in Roane county, in 1868.

II.—Iron Manufactures.

437. Iron is called the king of metals. It enters more into the domestic uses than all other metals combined. To it man owes his most efficient implements and tools. To it we are indebted for our steam engines, for our railways, for our telegraphic communication, for our great steam vessels, and for that power which, as intelligent beings, we exercise over the domain of nature. The magnetic compass which fixes the bound-

aries of our lands, and enables us to move with certainty and safety across fathomless oceans, owes its origin to the properties of this metal. The degree of enlightenment among nations is measured by its use; those consuming the greatest quantities being those that have made the greatest progress in the arts and sciences, and in the comforts and conveniences of civilized life.

438. There are three classes of iron products, viz.: *cast* or *pig iron, wrought* or *soft iron,* and *steel.*

439. Cast or Pig Iron.—This is the immediate product of the furnace, and has a specific gravity of 7.27. It has a granular structure, is hard, and readily broken. It may be melted at a high heat and run into moulds, by which means we obtain our cooking utensils, stoves, car wheels, and other "castings." It is not malleable, that is, it cannot be hammered as wrought iron or steel. About 48,000 tons of cast iron, valued at $1,000,000, is the average annual production of the State from about 21 furnaces. Of these five are in the Eastern belt, five in the Dyestone belt, and eleven in the Western belt. Establishments for making car wheels are in operation at Knoxville and Chattanooga.

440. The Smelting of Ore.—To make cast or pig iron when charcoal is used, the ingredients are put in the furnace in about the following proportions:

800 pounds ore.
80 pounds limestone.
20 bushels of coal.

This is called a *charge,* and will make about 350 to 400 pounds of iron. When put in, the furnace is intensely heated. The limestone is soon converted into lime, which unites with the sand, clay, and other impurities

of the ore, forming a fusible impure glass. This, being lighter than the melted iron, floats on top, and is drawn off as *slag*. The white hot charcoal takes the oxygen from the ore, and sets the iron free, which, settling at the bottom of the furnce as a liquid mass, is drawn off into small gutters or channels made in sand. When cooled it is taken up, and is called pig iron. The limestone is called a *flux*, because it melts with sand and clay into a *flowing* slag. The whole process is called *smelting*.

441. Wrought or Soft Iron.—This is most usually made of pig iron by remelting and stirring or working it when so melted. The process is termed *puddling*. The object of puddling is to expose every portion of the mass to the flames of the furnace, so as to burn out the carbon. With the loss of carbon the iron loses its fusibility, and becomes tough and malleable. It is also changed from a granular to a fibrous texture, and may be bent or twisted without breaking. When taken from the furnace it is hammered or rolled into bars. During the process its specific gravity is increased from 7.27 to 7.78.

442. Wrought iron is also made directly from the ore by a single fusion in small forges called *Catalan* forges. The ore is pounded, mixed with charcoal, and subjected to a moderate heat.

About eighteen of these forges are in operation in Johnson, Carter, and Campbell counties, making on an average each about 300 pounds of bar iron a day or about 800 tons annually, worth $64,000. Malleable iron is made from pig iron at Chattanooga for railroad bars, and at Knoxville into strips for making nails.

443. The presence of sulphur or phosphorus in wrought iron is exceedingly injurious. Phosphorus makes the metal *cold short,* or liable, when bent *cold,* to crack. *Red short,* due to the presence of sulphur, is the name given to iron which cracks when hammered at a welding heat.

444. Steel.—This is soft iron combined with carbon in the proportion of one part of carbon to about 140 of iron. It has a specific gravity of about 7.75. Steel is both malleable like wrought iron and fusible like pig iron, and stronger and harder than either. It is also susceptible of receiving a fine, cutting edge, which makes it of incalculable value in all the arts. Steel is manufactured to some extent at Kingston, and an association has been formed for that purpose at Chattanooga.

445. The advantages that Tennessee offers for the manufacture of iron are:

1. The ores are easily mined and easily reduced in the furnace, and are generally free from damaging impurities.

2. The ores exist in great variety, and by mixing them properly almost any grade of iron can be made.

3. These ores occur in abundance near railroads and navigable streams, which give an outlet to the markets of the world.

4. They lie near limestone and stone coal, and in regions where heavy forests of timber abound for the making of charcoal.

5. The mildness of the climate and the productiveness of the soil make the cost of living, and consequently labor cheap.

6. The low price of iron and coal property, by which a smaller amount of capital is required.

7. Cheap material for the construction of blast furnaces, and an abundance of water power.

CHAPTER XV.

Other Useful Minerals.

446. Under this head we shall embrace the ores of copper, zinc, and lead; gold, iron pyrites, oxide of manganese, barite or barytes, copperas, alum, petroleum, salt, nitre, epsomite, gypsum, and the mineral waters—all of which exist in greater or less quantities in the State.

I.—Copper.

447. The Copper District. Copper takes the third rank among the useful minerals of Tennessee. The copper-bearing district lies in Polk county and is confined to a mountain basin containing about forty square miles and elevated 1,800 feet above the sea. Hills and ridges characterize the surface of this basin, and it is rendered still more rugged by the presence of

gneissoid rocks and metamorphic slates, that stand out prominently in the valleys and on the slopes and tops of the hills and ridges. The sterile aspect of the valley is further increased by its nakedness, most of the timber having been cut off for the manufacture of charcoal, and much of that which remains being dead and in a decaying condition. The whole of the copper region lies in the Metamorphic formation. (See page 121). The strata of the valley dip at a high angle towards the south-east.

448. Copper Veins. The copper ores are in three veins, which lie at considerable distances from one another. These veins of ore are plainly marked. Upon the top of each vein is an impure iron ore called *gossan*, from a German word for "cap."

449. Ores of Copper. Beneath the gossan are found many varieties of copper ores, the principal ones being:

1. *Black Copper* or *Tenorite;* an oxide of copper, occurring as a black powder in dull black masses and yielding from 60 to 70 per cent. of metal. This, when the mines were first opened, was the most abundant ore.

2. *Cuprite* or the *Red Oxide of Copper,* associated with the last and yielding about 89 per cent. of copper. Its color is deep red, with various shades.

3. *Malachite* or *Green Carbonate of Copper,* having a light copper green color, yielding about 72 per cent. of metal when pure. Some of it admits of a high polish and can be used in making jewelry and ornamental work.

4. *Azurite* or *Blue Carbonate of Copper*, of a deep blue color, yields 69 per cent. of the oxide of copper.

5. *Copper Pyrite* or *Chalcopyrite*, a *sulphid of copper and iron*, having a brass yellow color. It contains, when pure, 34.6 per cent. of copper, 30.5 per cent. of iron, and 34.9 of sulphur.

This ore resembles gold, and iron pyrite. It is distinguished from gold by crumbling when cut, and from iron pyrite in yielding easily to the point of a knife, and in not striking fire with steel. This is now the most abundant copper ore worked in the furnaces at Ducktown, which is the name by which the copper region of Tennessee is known.

6. *Native Copper*, occurring in branching, or as it is called, *dendritic* forms, (from a Greek word signifying tree.) But a small quantity of this exists.

7. *Blue Vitriol* or *Chalcanthite* is the *sulphate of copper*. It has a sky-blue color and yields about 32 per cent. of the oxide of copper. Many beautiful masses have been met with in the mines.

450. Several other ores of copper are found to a limited extent, but have little practical value.

451. Copper Product. One incorporated company is in active operation. It employs between five and six hundred persons. The amount of refined copper made annually is about 1,400,000 pounds, worth over $300.-000. Sixteen furnaces are required for reducing the ores. One other mine has just been opened, called the London mine. This and the Eureka mine will be worked by individuals.

II.—Zinc.

452. Ores of Zinc. Three ores of zinc are found in Tennessee: *Sphalerite* or *Zinc Blende; Smithsonite,* and *Calamine.*

Sphalerite is a *sulphid of zinc.* It has a brownish yellow color with a resinous lustre, and is very brittle. When pure it yields about 67 per cent. of zinc and 33 of sulphur.

Smithsonite is a *carbonate of zinc,* of a white gray or light brown color, sometimes green. It is easily broken, has a pearly lustre and will effervesce with acids. It contains 64.54 per cent of the oxide of zinc and 35.46 carbonic acid.

Calamine. This is a *silicate of zinc,* of a whitish color, sometimes tinged with blue, green or brown. It dissolves in heated sulphuric acid. It contains 67.4 per cent. of the oxide of zinc, 25.1 silica, and 7.5 water.

These ores are all found associated more or less with galena, or the sulphid of lead. The two most important are the smithsonite and calamine. They occur in massive and in irregular veins in the Dolomytes of the Knox Group, and sometimes incrusted on the rocks in stalactitic and mamillary forms. Zinc blende is also found in the same formation associated with galena.

453. Zinc Deposits. The most extensive deposits of zinc ores yet found in the State are in Claiborne, Union and Jefferson counties. In Union county, near Powell's River, is a belt fifty or sixty feet wide, in

which the two ores, smithsonite and calamine, appear to be abundant. The belt is easily traced by the absence of trees.

The veins appear to run vertically into the rocks, and are from a few inches to several feet in thickness. These veins with the network of siliceous matter form the belt. The rocks on each side of the belt are shales and blue magnesian limestones of the Knox Group. (See page 128.) Some of the ore is now shipped to New York. Its quality is excellent.

454. At Mossy Creek, in Jefferson county, are numerous irregular veins of zinc ores in rocks of the same formation. For some years the oxide of zinc was made from the ores of the vicinity in an establishment at this place. This oxide is used for making white paint.

From Mossy Creek to Loudon, a distance of sixty miles, zinc ores are found at numerous points, but generally in small quantity.

III.—Lead.

455. Ores of Lead. *Galena* and *Cerussite* both occur in the State.

Galena is a *sulphid of lead,* and the most important ore of that metal. It is easily recognized by its leaden color and metallic lustre. When pure it contains 86.6 per cent. of lead and 13.4 of sulphur.

Cerussite is a *carbonate of lead,* and has the same composition as the white lead used in painting. It is usually stained a gray or brown color. Its contains

83.46 per cent. oxide of lead, and 16.54 carbonic acid. It effervesces with nitric acid. An analysis of that found at Leadvale, in Jefferson county, shows about 69 per cent. of lead.

456. Almost every county in the eastern part of the State has deposits of galena. Like the zinc, with which it is associated, it is found in the strata of the Knox Dolomyte. In Union county it presents itself in true veins generally in grains and lumps. In Washington county, at Bompass cove, it is disseminated in grains through the mass of rock, with pyrite and zinc blende. At other places, as in McMinn county, it appears in irregular masses or bunches.

Veins are also found in Monroe, Bradley and Jefferson counties, all of which have been worked to some extent. The one in Bradley county supplied some lead during the civil war. That in Jefferson county has been more recently worked. At this place both the carbonate and sulphid are met with. Many veins have been discovered in the Central Basin, one of some promise in Williamson county, but they have proved of no practical value. Some beautiful specimens have been picked up in Hickman, Henry and other counties.

IV.—Gold—Iron Pyrites, Oxide of Manganese, etc.

457. Gold. On Coco creek, in Monroe county, mining for gold was carried on for many years. The total amount taken from that place and coined has

not exceeded $50,000. The largest lump found was worth about $20. A gold-bearing quartz vein, found on a low ridge dividing the waters of Coco creek from those of Tellico, has been worked. No active operations are now carried on.

458. *Iron Pyrite or Pyrites.* A *sulphid of iron*, containing 46.7 of iron and 53.3 sulphur. It has a golden yellow color and is often mistaken for gold, which it very much resembles; hence the popular name of "Fool's Gold."

It exists everywhere in the State.

It is found associated with the copper ores in Polk county, and occurs in large beds in Carter and Greene counties. In Moore and Perry it forms considerable banks and occurs very generally in the Black Shale and Cretaceous strata.

459. It is of no practical value at present in Tennessee. Large quantities, however, as much as 66,000 tons, are annually raised in England for the manufacture of sulphuric acid. As population increases and the industries of the State multiply, this substance, now so useless, may make an important item in its future wealth.

460. The student should learn to distinguish it from gold. This may be done in several ways:

1. Gold is malleable and can be easily cut. Iron pyrite can neither be cut nor flattened by hammering.

2. Iron pyrite will strike fire with steel as readily as a flint: gold will not strike fire with anything.

3. Upon a whetstone a black mark can be made with iron pyrite; go'd gives a golden yellow metallic streak.

4. If coarsely pulverized and roasted in a shovel to a red heat, pyrite will burn: gold will remain unaffected.

461. *Oxide of Manganese.* This mineral is often associated with iron ore. It has an iron black color and makes an earthy black powder, by which it may be distinguished from hematite and limonite iron ores. From magnetite, which gives a similar powder, it may be distinguished by not acting upon the needle of a compass.

It is used in the arts for the manufacture of a bleaching material, and also for painting pottery and staining glass. Oxygen gas is also made from it. When mixed with iron ores and reduced in the furnace it produces a peculiar kind of iron, referred to on page 181.

Like iron, it is found in small deposits all over the State,—sometimes the specimens are beautifully crystallized.

462. *Barite, Barytes, or Heavy Spar (Sulphate of Baryta.)* A whitish mineral remarkable for its weight. It is often pulverized and mixed with white lead for making cheap paints. It is found in many localities in both East and Middle Tennessee. It usually occurs in veins associated with galena and is one of the minerals forming the gangue or enveloping material of that ore. About 1,000,000 pounds are mined annually in Greene, Washington and Jefferson counties. Considerable deposits are also met with in McMinn, Smith and other counties.

463. *Copperas* or *Green Vitriol.* This is a *sulphate of iron,* usually derived from iron pyrite. The Black Shale, when it is protected by overhanging rocks but exposed to the action of the atmosphere, crumbles and forms incrustations and deposits of impure copperas. This is due to the decomposition of the pyrite in the shale.

There are hundreds of such sheltered places called "Rock houses," in which masses of copperas may be found. One near Manchester, in Coffee county, is called Copperas Cave on this account.

464. Copperas was extensively manufactured from 1861 to 1865 at the copper mines at Ducktown from the refuse thrown out. This refuse consists in great part of iron pyrite. Copperas is employed in the manufacture of writing ink. It is also much used by dyers and tanners, and also in cities as a purifying, disinfecting agent.

465. *Alum.* This well-known mineral is frequently found associated with copperas in the "Rock houses" in Tennessee. It is formed by the decomposition of iron pyrite in contact with clay. It is largely employed for dyeing and medicinal purposes.

466. *Petroleum.* In Overton county there is a number of places where oil oozes from the surface, forming what are called oil springs. Several wells have been bored in that county and in Dickson. About 10,000 barrels were obtained in Overton county, but a want of transportation has put a stop to this industry.

467. The Black Shale, by distillation, can be made to yield oil. Some beds of this are so saturated with this oil as to burn awhile with a bright flame when thrown upon coals. For this reason it has often been mistaken for stone coal. It differs from coal in not burning to ashes, the lumps remaining the same size, the oil only burning out. The richest shale yields from thirty to forty gallons of oil to the ton. It is not uncommon in Great Britain to get sixty or eighty gallons to the ton. The coal oil used in the United States is refined petroleum, and is more extensively employed than all other materials for illuminating purposes.

468. *Salt.* Salt water has been found in Anderson, White, Van Buren, Warren, Overton and Jackson counties. In Anderson and White counties salt has been made within a recent period. The wells of White county yielded for many years fifty bushels per day. No salt of consequence has been made in the State since 1865.

469. *Nitre.* There are numerous caves in the limestone formation that supply a nitrous earth from which nitre is obtained by lixiviation. Works were in active operation at many points during the war of 1812, and for a while during the late war. Nitre is one of the constituents of gunpowder, the others being sulphur and charcoal.

470. *Epsom Salts* or *Epsomite* This mineral is found associated with alum and copperas.

471. *Gypsum.* No beds of gypsum have been found in the State of sufficient extent to be of any economic value. Small crystals have been observed in the soil east of Bay's Mountain. It is sometimes found in concretions of iron ore called pots, (page 186), and also mixed with nodules of iron in the Western Iron

Belt. It occurs in some of the lead veins. In some caves it takes the form of dazzling incrustations, often appearing as snowy rosettes, or icy vegetation. Beautiful specimens of *Selenite* or crystallized gypsum have been found in Williamson county.

472. *Mineral Waters.* Tennessee abounds in mineral waters, embracing Chalybeate, Sulphur, Magnesian and Alum. Chalybeate springs break out from the lofty heights of the Unaka range, as well as from the Cumberland Table-land. Along the base of the Clinch and Chilhowee mountains numerous springs of sulphur water take their rise, sometimes singly and sometimes in groups.

The counties of the Highland Rim are noted for the excellence and value of their sulphur waters. Henry and Hardin counties of the Plateau Slope, have many springs and wells which supply sulphur water. From some of these wells it pours forth in great volumes, forced up by pressure. The sulphur well in Henry county yields 100 gallons per minute.

The Black Shale is the most fruitful source of the sulphur waters all over the State. The alum waters of Hawkins, Grainger, Humphreys and other counties, also owe their origin to the same formation.

473. Many of these springs have reputations on account of their healing virtues. Many chalybeate springs are located in regions where the pure air, magnificent scenery, cooling breezes, and other healthful influences make them favorite resorts in summer for invalids and others seeking recreation.

CHAPTER XVI.

Useful Rocks and Clays.

474. We now turn our attention to such rocks and clays as are of practical use. The material with which we construct or ornament our buildings, build our roads, lay our pavements, make our fences, grind our flour, and fertilize our lands, are well worthy the attention of the student.

475. Limestones. Limestones suitable for building abound in nearly every portion of the State. Throughout the Valley of East Tennessee, the Highland Rim and the Central Basin, they constitute a large proportion of the rocks. They are of dull shades of color, running from a pearly gray through yellow, dove-colored, red, brown, and black.

Many of these limestones are heavy bedded and compact and furnish excellent and durable building rock. Others are laminated and sandy and crumble down by exposure to the weather.

In Bedford county a flexible limestone occurs which works easily. Another variety resists the action of fire and is called fire rock. Both are highly prized for building purposes.

476. The State Capitol is built of a laminated limestone that shows its sedimentary character in numerous horizontal bands. It is in reality a consolidated bed of calcareous sand. It is a bluish gray color, streaked with belts more or less dark. These belts are brought out prominently in the round columns and give them a pleasing appearance. p. 135.

477. Some limestones are excellent for making lime, and at many points on the railroads thousands of barrels are burnt and shipped every year.

478. Marble. This is a granular and crystalline limestone usually, but any limestone that will take a good polish and will look well after it is polished, is termed a marble.

Marble is an architectural rather than a geological term.

479. The marbles of Tennessee have acquired a richly deserved fame throughout the United States on account of their beautiful appearance and high polishing qualities. There are several varieties: the *black, gray, magnesian, fawn-colored, red variegated, conglomerate* and *breccia*.

The black marble, sometimes beautifully streaked with white veins of calcite, is found in Washington, Greene, Sevier, Blount and other counties in the eastern part of the State. It is easily worked, and makes quite a handsome appearance when polished. The black color is derived from the presence of bitumen.

480. The counties which have furnished the largest supplies of gray and variegated marbles are Hawkins and Knox, though many others, as Jefferson, Loudon and McMinn, have large quantities of it. In Hawkins and Knox the marble lies in strips sometimes many miles in length. It forms occasionally bold bluffs on the rivers.

481. The red variegated is prized for its pleasing appearance, and is used mainly in finishing and dec-

orating the interior of buildings. When polished it shines with a glowing brilliancy; the reddish and whitish spots that appear on its surface giving it a delicacy and richness of tint that is very beautiful and attractive.

482. This variety was used in ornamenting the State Capitol and many of the public buildings in Washington City and elsewhere. The Custom House at Knoxville is built of the gray marble found at the mouth of the French Broad river.

483. Brown and flesh-colored marbles are found in Jefferson and Hamblen counties in great abundance. A fawn-colored marble occurs in Lawrence county on the Highland Rim, overlaid by iron ore; and the gray and red variegated in Franklin, Lincoln and other counties in the Central Basin. Coarser marbles are found in Hamilton, Benton and Henry counties.

The Magnesian marble occurs only in the Knox Dolomite. It is too dull in color to be attractive, nevertheless it is considered a good building stone.

484. Some limestones are made up of rounded pebbles. When these are susceptible of a high polish, they constitute the *conglomerate* marble. When the imbedded fragments are angular, it is called *breccia* marble. Both conglomerate and breccia exist in the coves and valleys of the Unaka Range. Blount, Monroe and McMinn counties supply the greatest abundance. In some of the conglomerate and breccia marbles the imbedded gravel varies in color. When polished these look like mosaic work. About ten

large quarries of marble are in active operation in the State, and large quantities of the gray and red variegated are shipped north for ornamental purposes.

485. Gneiss or Stratified Granite. This is, ordinarily, a crystalline compound of quartz, feldspar and mica. When hornblende is in the rock it is called syenyte. The supply of this rock in Tennessee is very limited. Quarries could be opened at a few places in Johnson, Carter and Washington counties, from which gray and flesh-colored granites might be procured. A compact hard greenish granite in which the epidote replaces hornblende, called *Unakyte,* is found in Cocke county. It is very hard and resists well the erosion of water and the action of the atmosphere.

486. Sandstones. These are abundant in every part of the State, and are much used for building purposes. Some, as the Clinch mountain and Chilhowee sandstones, are very hard and difficult to work; others are soft and may be hewn with an axe. These softer sandstones are found above the St. Louis limestone, in the counties of the Highland Rim. A variety, beautifully laminated, is also found in the Upper Coal Measures. This sandstone is often nearly white and of good grain, making handsome structures. It is called a freestone, because it works easily under the hammer. Some of these sandstones of a bluish color make good whetstones.

487. Flagstones. Sandstones occur often in thin sheets or layers suitable for making pavements and hearths. These are called *flagstones*, and abound in

White, Bledsoe and other counties of the Highland Rim, and also upon the Cumberland Table-land. They occur in layers of varying thickness.

The iron limestones of East Tennessee are thin bedded and make good flag-stones.

488. Orange Sandstone. A red hard ferruginous conglomerated sandstone, is found in isolated masses in West Tennessee, and serves a good purpose for making foundations to buildings. It belongs to the Orange Sand formation and supplies a want in that portion of the State where building stones are very scarce. A notable outcrop of this occurs at Millstone, in Tipton county.

489. Saccharoidal Sandstone. A saccharoidal sandstone of a dazzling white color is found in Benton county. It is quite hard and durable.

490. Hydraulic Rocks. The best rocks for making hydraulic cement, that is, cement which will set under water and become hard, are impure carbonates of lime. The impurities consist of clay, silica, and often magnesia. These cement rocks abound in Hardin, Wayne, White, Decatur, Warren, Montgomery, Knox and McMinn counties. Several other counties furnish good quarries. Cement is now made in Hardin county, near Clifton, and is highly esteemed for plastering cisterns and making structures under water, as bridge piers. In Knox county cement is made of the brown calcareous shales.

491. Roofing Slate. In the Ocoee group are strata of a pale green, semi-talcose slate, from which good

roofing material may be made. This slate, when free from pyrite, is very durable. It splits easily into thin plates with smooth surfaces. Polk, McMinn, Monroe, Sevier, Blount and Cocke counties have an inexhaustible supply.

492. Millstone Grit. Stones suitable for the grinding of grain exist in various counties. The quartzose gneiss in the metamorphic formation has been used for making millstones. Several localities in Johnson and Carter supply such rocks that answer well for grinding corn.

493. The masses of chert included in the strata of the Knox Dolomyte have been found to make very excellent millstones. Some of it has a suitable cellular structure, especially where it has been exposed to the weather. Claiborne, Jefferson and Knox counties abound in this rock. It is a true buhrstone. Immediately below the Black Shale formation occurs a rock at places which consists of a bed of shells closely compacted and silicified, giving it where exposed a surface filled with cavities. The millstones manufactured from this rock are thought to be equal to the French buhr. Trousdale and Coffee counties have the finest presentations of this material.

Millstones for grinding corn have been made of the conglomerate of the coal measures.

494. Lithographic Stone. Almost all the stone used by engravers in the United States for making maps has been imported from Germany. Recently a bed of compact grayish colored limestone in McMinn county

has been tried and found to give excellent impressions. A quarry has been opened about eight miles south-east of Athens, and the stone is now coming into extensive use in Cincinnati and other points. This bed belongs to the Lower Silurian formation.

A fine compact stone of even texture and conchoidal fracture, underlying the sandstone of the Cumberland Table-land, may be used for lithographic purposes.

Specimens from Jefferson county show all the characteristic features of the lithographic stone of McMinn county.

495. Clay for Fire Bricks. Numerous deposits of fire clay are found in Stewart and Houston counties. The bricks made from it have proved as durable in fire as those brought from Liverpool. The color of the clay is a grayish white. Good fire clay should contain no lime, magnesia or iron.

The clays underlying some of the coal seams have been used in making fire bricks, as well as some of the grayish shales after being pounded into a powder.

496. Potters' Clay. Potters' Clay has an unctious feel and should be free from iron. Inferior pottery is made from a ferruginous clay in White county. The best clays in the State are of a whitish color and occur in Hickman, Perry, Wayne, Montgomery Houston, and in many of the counties of West Tennessee, especially Henry and Benton.

Kaolin. This results from the decomposition of feldspar, and is found in small quantities in Carter

county. This is the real *porcelain clay.* From this is made the best table ware.

497. Natural Fertilizers. The Green Sand of the Cretaceous formation in Hardin, McNairy and Henderson counties contain variable quantities of potash, which is one of the constituent elements of glauconite or green earth, a mineral of a greenish color, that is found disseminated among the masses of decomposed marine shells. Carbonate of lime is also a constituent of the shells. Phosphoric acid, a most powerful fertilizer, is also found in composition, and the value of the green sand depends in part upon this ingredient.

In some of the samples of green sand an analysis shows about 50 per cent. of silica, 10 of potash and phosphoric acid, and from two to ten per cent. of carbonate of lime, besides alumina and protoxid of iron. This mass of fertilizers will some day be utilized in reclaiming the waste places that now disfigure such a large portion of the enclosed lands of the State. (p. 162.)

498. Glass-making Material Good sands for the manufacture of glass are found in the State. The glass in the State Capitol was manufactured at Knoxville from sand obtained on the opposite shore of the Holston River. Good sand is also found at Coal Creek in Anderson county, near coal and limestone. The loosely compacted conglomerate or pudding stone found upon the top of the Cumberland Table-land, when blasted resolves itself into a bed of white sand and pebbles. The sand is separated, washed, exported

and used in the manufacture of the best plate glass. The sand of Hardin county has given satisfaction at the glass works where it has been used.

CHAPTER XVII.

Tennessee Soils; their Composition and Formation, Classification and Productiveness.

499. Soil and Subsoil. The *soil* is that portion of the earth's surface which can be cultivated, or which is usually stirred by agricultural implements. The *subsoil* rests immediately under the soil proper, and is also sometimes stirred by deep culture.

500. Composition of Soils. Soils consist of two parts, the *organic* and *inorganic*. The organic part is derived from vegetable and animal matter, and may be burned away by heat. The inorganic part remains after burning, and is composed of earthy and saline substances. The inorganic may be *soluble* or *insoluble* in water. The soluble portion consists of saline matter, and the insoluble of earthy material, which constitutes about 95 per cent. of the whole weight of the soils.

The principal insoluble ingredients are sand, clay and carbonate of lime, with a small per cent. of the

oxide of iron, which gives them color. Minute portions of magnesia, phosphates of lime and other ingredients are also found.

501. Formation of Soils.—The soils of the State, are derived mainly from the disintegrating or crumbling of the rocks which underlie them. Thus we have granitic soils, sandstone soils, limy soils and shaly soils, all differing in constitution and productive capacity.

The action of water in commingling the various ingredients which compose the alluvial soils give them a variable character not at all dependent upon the underlying rocks.

502. Hard rocks are changed into soil by the dynamic forces of heat, water and cold. The heat of the sun expands the rocks; the rain penetrates them and the cold converts the inclosed moisture into little wedges, which shell off or disintegrate the thin outer crust. The hardest rocks cannot resist these forces, and in time are turned into a loose soil.

The various acids, and mostly carbonic acid in rain-water, assist this process by dissolving the rocks. The action of these forces is called *weathering.*

503. The soils of the State may be classified as follows:

I. *Granitic.*—The soils of the Unaka Range; rather sandy, micaceous, and mellow. Exclusively belonging to East Tennessee.

II. *Sandstone Soil.*—Generally sandy and poor.

III. *Siliceous or Flinty.*—Fine, sandy soil of the "poor barrens" of the Highland Rim; generally much leached, with the original limestone matter dissolved out.

IV. *Sandy Soils.*—Underlying rock not consolidated; often fertile; important. Exclusively West Tennessee.

V. *Calcareo-siliceous.*—Very fertile; contains concretionary calcareous nodules; important. Confined to West Tennessee.

VI. *Calcareous Soils.*—The most important class of soils in the State; found in all divisions of the State; derived from limestone rocks, or rocks containing lime; strong, durable, and suited to all crops.

VII. *Green Sand.*—A calcareo-argillaceous mass underlying it, half consolidated into rock, often called rotten limestone, which is loaded with shells of many varieties, among which large oyster shells are specially prominent.

VIII. *Shaly Soils.*—Of varying fertilly; stiffer than the generality of soils.

IX. *Alluvium.*—Known as river bottoms; black with humus; often called "made lands."

504. The Granitic Soils.—These are confined exclusively to the counties traversed by the Unaka Range, and more particularly to parts of Johnson, Carter, Unicoi, Cocke, Monroe, and Polk. Owing to the ruggedness of the surface where they prevail, these soils have not been fully tested for the production of field crops. At places the soil has a deep black color, and is very friable. Buckwheat, timothy, and potatoes grow well upon the mountain heights.

505. Sandstone Soils.—There are five varieties of sandstone soils, all more or less distinct:

(*a.*) Chilhowee Mountain Sandstone soil.
(*b.*) Knox Sandstone soil.
(*c.*) Clinch Mountain Sandstone soil.
(*d*) Dyestone soil.
(*e.*) Soil of the Cumberland Table-land.

506. (*a.*) The *Chilhowee sandstone* yields a soil

of moderate fertility. Some areas are found that repay the labors of the husbandman in the production of potatoes, buckwheat, and garden vegetables. It also produces heavy forests of pine and chestnut, with thick copses of laurel, holly, and wild honeysuckle. Blue-grass, too, in places cover the bald places with its verdant turf.

It is confined to the mountain ridges of Johnson, Carter, Unicoi, Cocke, Sevier, and Blount counties. Of all the sandstone soils it is probably the most productive. This productiveness, however, may arise from the extreme humidity of the climate where it prevails, as compared with other portions of the State.

507. (*b.*) The *Knox sandstone soil* is unimportant, being confined to long, narrow, sharp ridges, where the surface, by reason of its steepness, is unsuited for cultivation. It is confined to the ridges of the valley of East Tennessee, and produces timber in limited quantities, but is not well adapted to the grasses.

508. (*c.*) **The Clinch Mountain Sandstone Soil.**—This occurs mainly on the south-east side of Clinch Mountain, which traverses Grainger, Hancock, and Hawkins counties; on Powell's Mountain, which lies in Claiborne and Hancock counties; on Lone Mountain, a continuation of the latter, in the counties of Anderson and Union, and on some of the ridges of the Bays Mountain group, which lies mostly in Hawkins county. It is thin, sandy, and poor, sparsely timbered, and has immediately underlying it large sheets of sandstone. It has a pale yellowish color.

and is almost entirely destitute of plant food. It is probably the most unproductive soil in the State.

509. It may be mentioned as a singular fact that the north-west face of these mountains has a calcareous soil, exceedingly fertile and highly productive. It is curious to observe the exuberance of vegetable growth on the one side and the poverty on the other. Stately trees with leafy tops, covered with vines and creepers, making an impervious thicket, characterize the one side in its wild state, while the other, covered with a hard shield of sandstone, has a poor soil and a thin growth.

510. (*d.*) **The Dyestone Soil.**—This results from the weathering of the greenish calcareous shales and fine sand of the Dyestone group, and is found on the east side of White Oak Mountain in James and Bradley counties, and on the slopes of the smaller Dyestone ridges. The rocks of this group are more varied in chemical composition than those of the other sandstone soils, which gives more vitality to the resulting soils. This is manifested in the better growth of timber, though owing to the ruggedness of the country very small areas have been brought into cultivation.

511. (*e.*) **The Soil of the Cumberland Table-land.**—This is the most important of the sandstone soils, inasmuch as it extends over an area of about 5,000 square miles. This soil is usually sandy, porous, and infertile, and rests upon a coarse, ferruginous sandstone. Nevertheless, at the foot of some of the knobs and ridges, and in some of the depressions that occur upon the mountain top, there are areas of moderate fertility.

512. The defects of this soil are porosity, and a want of calcareous matter. Yet, nothwithstanding its porous nature, there are many small swampy places in which the soil is of a dark blue color, sometimes nearly black. The subsoil of these places is a blue clay, and almost impervious to water. These swampy spots or swales are usually covered with a coarse, rank grass, and spotted with beds of fern, which form a thick mat. Such places abound in half decomposed vegetable matter, and if drained and exposed to the correcting influences of the atmosphere, they soon become productive.

513. The best soils of this division have a yellowish red subsoil, with a thin coat of vegetable mold on the surface. Though thin, the soils are easily cultivated. The greatest agricultural value of this portion of the State is to be found in the abundance of wild and nutritious grasses that cover the surface during the summer months, affording a rich pasturage. Apples and grapes also yield plenteously. The soil is also well adapted to the growth of garden vegetables, and especially Irish potatoes.

514. **Siliceous or Flinty Soil.** — This is derived from the crumbling of the cherty masses, and prevails in most of the counties of the Highland Rim. It is the soil of the barrens. Wherever the subsoil is so porous as to permit the calcareous matter to be leached out, the surface soil becomes hungry, thin, and barren. But when the underclay is of a deep red color, unctious and tenacious, the soil rivals the

best in the State in productiveness, and grows in great abundance the staple products.

Both kinds of soil, the leached and unleached, are found associated together on the Highland Rim, and are underlaid by beds of chert. The unleached is more properly called a calcareous soil.

515. The siliceous soil of the barrens produces a coarse, rank, meadow grass, which, when young and tender, is highly relished by cattle. The unleached or calcareous soil of the barrens is noted for growing excellent tobacco and wheat.

516. Sandy Soils.—Under this head are included the varieties of mellow upland and highland soils which occur in West Tennessee. They are based, not on solid rock, like the sandstone soils mentioned, but upon unconsolidated strata of matter mainly sandy. The soils resulting have about the same character. They are called sandy, or arenaceous, because this mineral feature greatly predominates. They are generally red or yellow, from the presence of a notable quantity of ferric oxide and silicate.

517. It does not follow because a soil is "sandy" that it is poor. The clay and calcareous matter that some contain give them a degree of body and vitality which make them, for many crops, highly valuable lands. The way they lie, too, is an important consideration. If high, plateau-like, or gently rolling and well drained, such lands are often highly esteemed by the farmer; when, if steep or very hilly, they are not prized. In the latter case the soils have the

same components, but, under tillage, are easily washed and made comparatively worthless. The best cotton lands have these sandy soils.

518. Calcareo-siliceous.—The *calcareo-siliceous* soil occupies the eastern parts of the counties of Obion, Dyer, Lauderdale, Tipton, and Shelby. It presents an ashen aspect as to color and consistence, but sometimes it is of a reddish cast, occasionally black, and oftentimes mulatto in color. It contains more calcareous matter than the other unconsolidated formations of West Tennessee, with the single exception of the Green Sand or Rotten Limestone. It is not unusual to meet imbedded in it concretions of carbonate of lime. At some points they may be gathered by the bushel. The soil is similar in character to the formation—calcareous, siliceous, or fine grained, ashen, and sometimes slightly reddish and black. Its lands are among the most fertile in the State.

The soil owes its good qualities, not to its chemical composition alone, but also to its fine powdery condition. Tobacco, cotton, wheat, oats, clover, and the grasses grow luxuriantly upon it, while the native growth of timber, especially in Obion and Dyer, is unsurpassed.

519. Calcareous Soils.—These soils owe their fertility to the large amount of calcareous matter, which they contain. They rest upon the different varieties of limestone found in the State, and differ mainly in having a greater or less quantity of siliceous material

or clay in their composition, making them friable or stiff, as one or the other ingredient predominates.

In durability, productiveness, and extent, they surpass all other soils in the State, with the exception of the alluvial. They constitute the wheat, tobacco, blue-grass, and much of the cotton lands of the State, and are found in all the minor valleys of the Valley of East Tennessee, in the Central Basin, on much of the Highland Rim, and in the Western Valley. But few of them occur in West Tennessee. These soils are classified according to the character of the prevailing limestone, and form the best farming areas. They cover in the aggregate one-fourth of the surface of the State.

520. Green Sand Soil. — This soil is a kind of siliceous loam, resting upon an interesting formation in West Tennessee, which is, in the main, sand and clay intermixed, having as characteristic ingredients a considerable amount of carbonate of lime, and numerous green grains (p. 162). The formation from which this soil is derived is loaded with shells. These supply the soil with fertile ingredients, and make it friable and productive. It is well adapted to the growth of cotton and corn, and some portions to the growth of wheat. This soil is confined almost entirely to the eastern part of McNairy and Henderson counties, and belongs to the Cretaceous formation.

521. Shaly Soil. — As a top formation shale is rare. In a few of the narrow valleys of East Tennessee the Black Shale forms the basis of the

soil. Such a soil is cold, clayey, unimportant, and unproductive, except for the grasses.

522. Alluvial Soil. — This altogether occupies a large area in the State. Nine hundred square miles of alluvial soil lie upon the Mississippi river. It is also the soil of the lowlands of the Tennessee and Cumberland rivers, and of all their tributaries. The whole State is furrowed by rivers, creeks, and rills, each of which has lying upon its margin more or less alluvial soil. Some of the highland counties, as Perry, are alternate ridges and valleys. The alluvial soils differ greatly in character, color, aptitudes, and productive capacity, depending in part upon the formations of the surrounding highlands and upon the frequency or infrequency of the overflows. Where the water-courses flow through or over limestone formations, the sediment which they deposit is highly calcareous. When the streams gather their waters from gravelly hills or sandstone ridges, the soil is more deficient in carbonate of lime, and usually not so productive. The character of the alluvial soil is generally determined by the region through which the stream flows.

523. On many of the streams are terraces, elevated high above the stream-beds, and not subject to overflow, which have all the characteristic features of the low alluvial soils. These fluviatile deposits are exceedingly rich in plant-food, and make our most generous soils. Their perfect drainage and freedom from

overflows make them very valuable and desirable. For the growth of wheat they are especially adapted.

524. These constitute the principal varieties of soil in the State, but they often overlap and run into one another, giving an infinite variety, making soils warm or cold, light or heavy, loamy, marly, hungry, leachy, sweet, sour, clayey, marshy, compact, tenacious, fine, coarse, gravelly, and rocky.

525. The productiveness of soils do not depend altogether upon the constituent elements, such as lime, potash, soda, phosphoric and sulphuric acids, and vegetable matter, but upon climatic influences, surface exposure, subsoil, drainage, degree of pulverization and culture. Drainage is especially important.

526. Standing water is destructive of our field crops. On the other hand, the soil must not be so porous as to permit the fertilizers to filter to a depth beyond the reach of plants. For the purpose of production the best condition of a soil is to be thoroughly pulverized and well drained of its surplus water, yet with an underclay that will catch and hold all fertilizing ingredients.

QUESTIONS.

[The figures refer to the paragraphs in the body of the book.]

INTRODUCTION.

1. In what are the young people invited to join? What is the object of the survey? What are the external features making up the surface of the country? What constitutes the earth and rock foundation?

2. In what ways is such knowledge useful?

3. Why is a plan desirable?

4. How ought the State to be first regarded? What must we know? What must we learn about the surface?

5. What can we then study?

6. What will be the third step? What preparation is required for this? What will we study in the field? What about the rock-beds and strata?

7. What about the fourth stage? What is a stratum? A formation? What is to be determined about them?

8. What is the subject of the fifth and last division? What is included in this class?

PART I—CHAPTER I.

How is the State considered in Part I?

1. What is the subject of Chapter I?

2. What does the State resemble in form? Its width? Its length? Area?

3. What does the map on page 9 show?

4. Between what, and in what direction does the State lie? What is the elevation of the North Carolina boundary? What that of the lowlands on the Mississippi river? What do the eastern mountains form? What lies at their foot? What is the elevation of the Valley of East Tennessee? In what direction does the general surface descend? In what two directions do the rivers flow? Their mean direction?

5. What is said of water courses? What are the principal rivers?

CHAPTER II.

What is the subject of Chapter II?

6. Into what two portions may Tennessee be divided? What does the eastern portion embrace? With the map what can the student see? This part of Tennessee is a section of what?

7. For what is the belt of country between the Gulf of Mexico and the Gulf of St. Lawrence remarkable? What is the name of this belt? Its length and width?

8. Give some of the names of the mountains and valleys? What is said of the Alleghany Range? What is the character of many of the valleys?

9. What is said of "up and down" and "across the country"?

10. What are great valleys and what are minor valleys?

11. What valley is presented as an example? Between what does this valley lie? How does it appear from high summits?

12. For what is the Appalachian Belt singular?

CHAPTER III.

The Subject of Chapter III?

13. Into what natural divisions is the surface of the State divided? What is the first natural division? Describe it. Second? Third? Fourth? Fifth? Sixth? Seventh? Eighth?

14. Which is the largest natural division? What next? What two divisions are next in size? What are the smaller divisions? Give the areas of each?

15. How do these natural divisions lie with respect to the State? In what are the three most easterly divisions included?

16. How many civil or political divisions? Name them. Describe East Tennessee. Middle Tennessee. West Tennessee. How many counties in each?

CHAPTER IV.

What is the subject of this Chapter?

17. What is meant by climate? To what is the character of climate related? How does climate affect the industry of a country? How is the subject of climate treated?

18. What is mean annual temperature? Give the mean annual temperature of the Unaka Range, and the other natural divisions? What is the greatest difference in these means? To what is this due? What is the difference in temperature of the southern and northern boundary?

19. How does the mean temperature of Tennessee compare with other regions? What are isotherms? Through what country do the Tennessee isotherms extend? Do the lines of equal heat correspond with the lines

of latitude? Is the variation of heat in Europe the same as in Tennessee? Give illustrations. What effect does this have upon vegetation?

20. What is said of the average or mean summer heats as compared with winter means? About what are winter means? The summer mean of the Unaka Range? Of the Valley of East Tennessee? Table-land? Highlands? Central Basin? West Tennessee? What is the highest recorded temperature? The greatest degree of cold? Which is the coldest month? The warmest month?

21. What is said of ice and ice houses?

22. What is said of the period between killing frosts, and what does it measure? The average number of days between killing frosts?

23. In what months do the most destructive frosts occur? The difference in time between killing frosts in the northern and southern parts of the State? What effect does this have upon agriculture?

24. Give the average annual fall of rain upon the globe. In the Torrid Zone. Temperate Zone. Frigid Zone. What is the average rainfall of Tennessee in inches?

25. What does the table in this paragraph show? In what year did the greatest fall of rain occur? The least?

26. In what month does the greatest quantity of rain usually fall? The dryest month?

27. What is the annual fall of snow?

28. What is said of the two systems of winds? What of the lower? The upper? What effect does the commingling of these two systems have? What winds are most desirable?

29. What fact has been established?

30. For what is Tennessee remarkable? In what is this seen? Give illustrations.

PART II.

What is the subject of Part II?

31. What is said of the natural divisions, and how are they now to be considered?

CHAPTER V.

What is the subject of Chapter V?

32. What is the Unaka Range? How does it compare with other Appalachian ranges? Average elevation? Elevation of highest peaks? Its high crest forms what boundary? What is the width of the portion in Tennessee? Area?

33. What the character of the Unaka Range? Which is the main axis? What is meant by axis? Give the names of some of the most important parts.

34. Where do the most westerly of the Unaka Range lie? How are

they arranged? What is this line of mountains called? Give the names of some of these?

35. What of included valleys and coves? What is said of the cultivated part of Johnson county? What are other coves?

36. What cut the Unaka Range into sections? Where do these rivers rise? What is the direction of their flow? How many are there?

37. What are the highest summits of the Unaka Range called? Describe the Balds.

38. What is said of the views from the Balds.

39. Descending from the mountains, what do we enter? What is said of this valley? Between what does it lie? What is the average distance between these divisions? What city near its centre? What at its south-western corner? What its area?

40. What is the average elevation of the Valley of East Tennessee above the sea? Its elevation on the Virginia line? At Knoxville? On the Georgia line?

41. What do we find in crossing the Valley of East Tennessee? Why is it called a fluted area?

42. What is said of the ridges of the Valley? Into how many classes are the ridges grouped?

43. What is said of the mountain ridges? What of White Oak mountain? Clinch mountain?

44. What mountains are mentioned in this paragraph?

45. What is said of the broad ridges?

46. What of the narrow and sharp ridges? What of the red hills?

47. What is said of the minor valleys and coves?

48. What about the creeks of the valleys?

49. What kind of rocks in the valleys and coves?

50. What is said of Sequatchee Valley? What embraces it?

51. What natural division follows next in order? Describe it. What its elevation above the Valley of East Tennessee? What above the sea? Area? Point it out on the map. How does its eastern edge compare with its western? By what is Walden's Ridge cut off from the main Table-land?

52. What is said of the surface of the Table-land? What of its soil?

53. How does the Table-land impede free intercourse? By what is the Tennessee river deflected?

CHAPTER VI.

What is the subject of Chapter VI?

54. What divisions were considered in last Chapter? What in this? What is the limit of elevation in these divisions?

55. Describe the Highland Rim. Height above the sea. What has been washed out in the centre? Why is it called a rim?

56. Trace it out on the map. How does the eastern portion compare with the western? What is the area of the Rim?

57. What is said of the surface of the Rim? Soils? Iron ore banks?

58. What is the area enclosed by the Rim called? How does this division of the State compare with the others in importance? Trace it out on the map. What city within it? What rivers? Its length? Width? Area? Depth below the Rim?

59. With what is the Basin compared? Suppose the rivers were dammed up, what would result? What would be the depth of this lake at Nashville?

60. What division follows next in order? What is said of it? Its width? Area? Elevation?

61. What is included in the Plateau Slope? How does it compare with the other divisions? What is said of the absence of *hard* rocks? Does it differ in aspect from Middle Tennessee?

62. Describe this division, and point it out on the map. What city near its centre? What in south-west corner? What is said of its eastern border? What of the Tennessee Ridge? How does the Plateau terminate at the west? What are the bluffs?

63. What of the rivers in this division? Give the area.

64. What is the remaining division to be noticed? Describe it. What of the soils and lands? By what is it cut into parts? Give its area. Elevation above the Gulf of Mexico.

PART III.

What is the subject of this part?

66. What was completed on the last page? In this part what is to be studied?

67. What does the word Geology signify? Give its meaning further.

68. What does Geology explain? What does it point out? What is every stratum like?

69. Of what else does geology inform us?

CHAPTER VII.

What is the subject of this chapter?

70. Of what do rocks consist? What three minerals constitute granite? What mineral constitutes limestone? What is said of the number of minerals entering the rocks of Tennessee? How many are there? Name them.

71. What are ores?

72. What are common flint and sand? What is the material of grindstones and whetstones? What is the most common ingredient of rocks? What are the characteristics of quartz?

73. What is said of the crystals of quartz? What are geodes?

74. What are rock crystals? For what are they used? What is an amethyst? What false topaz? Mention other varieties of quartz.

75. What varieties of quartz are included under concretionary quartz and chalcedony? What do they resemble? To what does the word *concretionary* refer? What are concretions?

76. What lustre has chalcedony? What is Cornelian? What is Agate? Banded Agate? Other varieties? What is Onyx?

77. To what is flint allied? What is hornstone? Chert? Buhrstone?

78. What is Jaspery Quartz?

79. In what respect does Opal differ from quartz?

80. What is the chemist's name for quartz? Give the composition of silica.

81. What does silica form with alkaline substances? What is a silicate?

82. How does the composition of many minerals compare with that of glass?

83. What is said of quartz rock.

84. What of beds of sand? Of what are sandstone rocks composed?

85. What is said of *hardness?* How do mineralogists determine the hardness of minerals? Illustrate. How many minerals compose the scale of hardness? Which is the softest mineral of the scale? The hardest? What place does quartz occupy in the scale?

86. What is the first member of the scale? Second? Third? Fourth? Fifth? Sixth? Seventh? Eighth? Ninth? The last?

87. What is the composition of apatite, and what may it be considered?

88. What is Sapphire? To what class of substances does alumina belong? What is the characteristic constituent of common clay?

89. What is corundum? What is emory?

90. What is the diamond? What are the three different forms of carbon? Give exampless.

91. What is Calcite? What stalactites? When are rocks said to be calcareous?

92. What are said of the crystalline forms of calcite?

93. What is Iceland spar?

94. What is the composition of calcite? If calcite is heated in a kiln, what will result? How else may carbonic acid be driven off from calcite or limestone? What is meant by *effervescence?* How may calcite be distinguished from quartz or gypsum?

95. Under what conditions are calcite or limestone dissolved in water? What is said of rainwater? How is hard or limestone water produced?

96. To what do caves owe their origin? Explain the formation of a cave.

97. Describe the formation of stalactites. What are stalagmites?

98. What is travertine? What is calcareous tufa?

99. What does dolomite resemble? How does it differ in composition from calcite?

100. What are rock masses of dolomite called?

101. What rock does feldspar help to form? In what division of the State is it found? What is the chemical name of feldspar? Give some of the varieties of feldspar.

102. How may the feldspars be distinguished from quartz?

103. What is meant by cleavage?

104. From what is the principal ingredient of clay derived? What are pure clays? What is kaolin? What are common clays?

105. How is mica recognized? In what rock is it found associated with quartz and feldspar? For what is it used?

106. Describe mica.

107. What is said of the composition of amphibole and pyroxene? Are they easily distinguished? What is asbestos?

108. By what other name is amphibole known? How does syenite differ from granite?

109. Mention the varieties of pyroxene?

110. What is said of the crystals of garnet?

111. What is said of tourmaline?

112. Describe talc. What is steatite?

113. What is said of chlorite?

114. What is serpentine? What is verd-antique marble?

CHAPTER VIII.

What is the subject of this chapter?

115. What was considered in the last chapter, and what do we consider in this?

116. What are rocks?

117. What were the rocks of Tennessee once? How did they become compact?

118. What is said of deposits now accumulating?

119. What of the hardening of the beds? What of the strata of West Tennessee? What of the Gulf of Mexico?

120. What is said of the purity of the original beds and of the rocks?

121. Into what three classes are the rocks grouped?

122. What are sediments, and what sedimentary rocks? What other terms are applied to these rocks?

123. What does metamorphic mean? What is said of the action of heat on sedimentary rocks? What are metamorphic rocks?

124. What is said of igneous rocks? What are dikes?

125. What is said of sandstones and related rocks? What are some of the kinds of sandstones? What are quartzytes?

126. What is a conglomerate? What is breccia? What does ferruginous mean?

127. What is said of limestones?

128. Enumerate the varieties of limestones?

129. What are fire rocks?

130. To what class of rocks do the limestones of Tennessee belong?

131. To what species of rocks do stalactites belong?

132. What is said of magnesian limestone or dolomyte?

133. What is said of the dyestone ore?

134. What are shales? What is shale often improperly called? Describe shale.

135. What is bituminous shale?

136. What is alum shale?

137. What are true slates?

138. What are examples of clay slate? Describe clay slate. How does this differ from shale? What is slaty cleavage?

139. What is schist?

140. How does mica slate differ from mica schist?

141. How does hydro-mica slate differ from the slates just mentioned?

142. What is said of granite in Tennessee? How does it differ from the rocks already mentioned?

143. What is said of the color of granite?

144. When is a granite-like rock called syenyte? Now may hornblende be distinguished from black mica? What is unakyte?

145. How does gneiss differ from granite? What mountains in Tennessee are made up of gneiss and gnessoid rocks?

146 Does gneiss pass into mica schist or mica slate? What are the varieties of hornblende rocks? What is protogine?

147. In what series are the rocks just described included?

148. What are trap rocks? Are they important in Tennessee? Describe trap further.

149. What is the rock of the Palisades of the Hudson river?

150. Name some of the varieties of trap rock.

151. What is dioryte?

152. What is amygdaloid?

153. What is porphyry?

154. What is said of lavas or volcanic rocks?

155. What is trachyte? Name other varieties of lava.

CHAPTER IX.

What is the subject of Chapter IX?

156. What are we to learn in this chapter?

157. In what three forms do rocks occur?

158. How does this classification differ from that given on pages 60 and 61?

159. When are rocks stratified?

160. What is a layer? A stratum? A formation?

161. What is said of the rocks of Tennessee?

162. What is illustrated in the figure?

163. What is a section?

164. What is said of sections in deep gorges? What of the cuts and gorges in Tennessee?

165. What is stated in this paragraph?

166. What is said of horizontal layers, and what does the figure illustrate?

167. Explain jointed structure. What are joints?

168. What is said of the extent of strata?

169. What example is given? Describe the extent of the Black Shale.

170. What was the original position of the strata in Tennessee?

171. What is said of the raising of the strata out of the ocean? What of the wrinkling of the strata? What effects were produced by this action?

172. By what are the folds of strata illustrated?

173. What is said of the bending of strata?

174. What does figure 10 illustrate? What is said of Sequatchee Valley?

175. What is an axis? An anticlinal axis? A synclinal axis? What are decapitated folds?

176. When does a rock outcrop?

177. What is meant by *dip?*

178. What is meant by *strike?*

179. What is said of folded and inclined rocks in Tennessee? How do the rocks dip in the Valley of East Tennessee?

180. What is figure 17 intended to illustrate?

181. How have faults been formed? Point out the places of faults in figure 17.

182. What is said of faults in East Tennessee?

183. What do figures 13 and 14 illustrate?

184. What is said of the study of strata?

185. Where should the student begin?

186. What is said of unstratified rocks?

187. How are veins made?

188. What is said of veins in Tennessee?

189. What about the denudation of strata? How has the elevated matter been carried away?

190. What about the denudation of strata at Knoxville? At Chattanooga? What are other examples of denudation?

191. Of what is Sequatchee Valley an example? How was this valley formed?

192. What kinds of rocks yield most readily to wear and denudation? What are valley making rocks? What are ridge and mountain making rocks?

193. Why do the valleys and ridges of East Tennessee run in a *north-west*, north-easterly, and south-westerly direction?

194. How are table lands formed? What of the Cumberland Table-lands?

195. When are strata said to be unconformable?

196. What do the rocks contain embedded in them? What are said of the rocks about Nashville?

197. What are fossils?

198. What is said of the fossils in a formation? What of the fossils at Nashville and McMinnville? What illustration of the use of fossils is given?

199. What is paleontology?

200. What is necessary for the student to know? Into what two great groups are the animals divided? What are Vertebrates? Invertebrates? How many sub-kingdoms in all? What does the table on page 93 give? What are examples of animals of the simplest organization? Of the highest organization? What are the sub-kingdoms of the Invertebrates? Describe them. What sub-kingdom is included under the Vertebrates? What four classes of Vertebrates are there? Name them and define them.

201. What is a sponge? What are Rhizopods?

202. What animals are included among the Radiates?

203. What is included in the group in figure 22?

204 What is said of Crinoids?

205. What of the abundance of Crinoids in the ancient seas?

206. Describe the form of a sea urchin.

297. What are Cephalopods?

208. What are Gasteropods?

209. What are Acephals?

210. What are Brachiopods, and how do they differ from Acephals?

211. Describe the Bryozoans.
212. How are the Articulates divided?
213. What is said of Trilobites?
214. What is said of Ostracoids? What is a Barnacle?
215. What is stated in this paragraph?
216. What of the Selachians?
217. What of the Ganoids.
218. Into what two great groups are plants divided? Define the Cryptogams. Define the Phenogams.
219. Into what three classes are the flowerless plants or Cryptogams divided? Describe the Thallogens. Describe the Anogens. Describe the Acrogens. What do the Endogens include? What do the Exogens include? Into what two orders are the Exogens divided? What is said of the Cycads? The Conifers? The Angiosperms?
220. What is the first condition of the earth, according to geologists?
221. What of the water from Artesian wells? What other facts go to show the heated condition of the earth?
222. What is said of the formation of the crust of the earth?
223. What of the ocean and stratified rocks?
224. What was the character of the first strata?
225. What of dry land, and the creation of plants and animals?
226. What is said in this paragraph?
227. What is stated as the present condition of the interior of the earth?
228. What about the thickness of the crust of the globe? What is the rate of increase of temperature as one descends in the earth?

PART IV.

What is the subject of this part?
229. What was studied in the last part? What are we prepared now to consider?
230. What is first considered?

CHAPTER X.

What is the subject of this chapter?
231. How is past time divided? What was made during each formation?
232. Into what are the ages divided? What is their correspondence to each of these periods? Mention the example given.
233. What is presented on pages 108 and 109?
234. What are grand or largest divisions in the section? Name the times.
235. In what part of the section are the formations of Tennessee indicated?

236. How many ages have geologists recognized?

337. What is the first age? What is the meaning of *Archæan?* During the Archæan time what rocks were made? What is said of life in this age?

238. Where are the principal outcrops of rocks of this age?

239. Do Archæan rock appear at the surface in Tennessee?

240. What is the second age? What animals flourished in this age? What covered the continents?

241. What kinds of rocks were made during this era?

242. What are the two divisions of strata of the Silurian age?

243. What is the third age? What animals flourished during this age?

244. What of the rocks of this age?

245. What is the fourth age? What is said of the lands of this era? What of the forests and plants? What of the animals?

246. What was the character of the strata?

247. What was the fifth age? For what is it remarkable? What of the plants?

248. What strata originated in this era?

249. What is the sixth age? What of the animals of this age?

250. What of the continents? Forests?

251. What of the rocks formed in the era?

252. What is said of the strata of West Tennessee?

253. What is the seventh age? What covered the continents during the first period of this age?

254. What happened to the lands in the second period?

255. What is the *drift?* What of the drift north and south of the Ohio river? What is the relation of the Orange sand to the drift?

256. What of the climate in this period? What of the Mammals? What of the Invertebrates?

257. What happened to the continent in the third and last period of the age of man? How are the terraces of the rivers formed?

258. What names have been given to the three periods of the Quarternary Age?

259. What formations occur in Tennessee, as shown on the map?

260. Point out the areas of each formation?

261. What is the first Tennessee formation? How much of the surface of the State does the Lower Silurian form? How is the Lower Silurian indicated on the map?

262. What is its thickness? What kinds of rocks?

263. What is the second Tennessee formation? Of how many members does it consist, and what is its entire thickness? How are the outcrops of the Upper Silurian indicated on the map?

264. What is the third Tennessee formation? What is the sole representative of this formation in Tennessee? How is it indicated on the map?

265. What is the fourth Tennessee formation? How many members has it, and what is its aggregate thickness? What is the character of the lower third? What of the upper two thirds?

266. What are the surface rocks of the Highland Rim and Cumberland Table-land?

267. What is the fifth formation of Tennessee? Of what age is this the only representative in Tennessee? Of what does the Cretaceous formation consist? What is its thickness? To what part of Tennessee is the group confined? How is it indicated on the map?

268. What is the sixth formation? What are the beds of this formation? What is its thickness? To what part of the State confined? How represented on the map?

269. What is the seventh formation? This is a group including what?

CHAPTER XI.

What is the subject of this chapter?

270. What was treated of in the last chapter, and what is proposed in this?

271. What formations are included in the Paleozoic Time? What is said of the comparative importance of these four formations?

272. Why is this time called Paleozoic? What of Brachiopods? What of Ganoids?

273. Are Archæan rocks included in Tennessee formations? What is their thickness in Canada? Into what two formations are they divided?

274. What formation gives so much bulk to the Paleozoic rocks in Tennessee?

275. Into what six divisions are the Lower Silurian formation of Tennessee grouped? Name them. Give the general characteristics of each.

276. Which of these belong to the Primordial period? Which to the Canadian?

277. What is the principal formation of the Unaka Range? How is it represented on the map? Of what does it consist? By what changed?

278. Why is the group named Ocoee?

279. How are the Ocoee rocks changed near the North Carolina line? How does it happen that granite-like rocks are found in Tennessee?

280. What formation follows the Ocoee? This is a mass of what? Of what mountains is this sandstone the formation?

281. How are these mountains indicated on the map? What of the fossils?

282. What is said of the rocks of the Knox group?

283. What are the divisions of the Knox group?

284. What is said of the Knox sandstone? What of the Knox sandstone ridges?

285. Give the names of some of these ridges?

286. What is said of the Knox shale? What towns are upon it?

287. What of the Knox group in the north-eastern part of the Valley?

288. What of fossil shells and Trilobites?

289. What of Knox Dolomyte? What is its thickness?

290. Of what does the division consist? What is the character of the rocks at the base?

291. What is said of chert in the Knox Dolomyte?

292. What does this section illustrate?

293. Give the names of some of the Knox Dolomyte ridges. What towns are situated on the Knox Dolomyte?

294. Where is the Knox Dolomyte found, out of East Tennessee? Where does the Wells Creek Basin lie?

295. How do the formations outcrop in the Wells Creek Basin?

296. What is said of the Lenoir limestone?

297. What is the character of the Lenoir limestone in the north-eastern part of the Valley? In the western part of the Valley?

298. What of fossils in the Lenoir limestone?

299. How may the Lenoir limestone be regarded? What towns are upon it?

300. What is said of the Lebanon group? To what divisions of the State does it belong?

301. What about the Glade limestone?

302. At what town are the rocks and formations well displayed? What other towns in the Basin are located upon these rocks?

303. What is said of the Lebanon group in the Valley of East Tennessee?

304. What of the group in the Sequatchee Valley?

305. What is their character in the vicinity of Knoxville? What is said of the marble? What of the Lebanon group on the eastern side of the Valley?

306. What of fossils in the Lebanon group?

307. In what division of the State do the strata of the Nashville group outcrop? How thick are they in the Basin?

308. What of the Nashville rocks in the western part of the Valley? What in the eastern part?

309. Upon what is Nashville built? Give a synopsis of the rocks as they occur around Nashville?

310. What is said of the Orthis bed?

311. What of the Orthis bed at Clifton?

312. What towns are located upon the rocks of the Nashville group?

313. What valleys in East Tennessee show the Lebanon and Nashville rocks? What towns upon them?

314. What is the character of the Nashville group about Knoxville? Further east? How thick is the shale?

315. What is the rock of the eastern knobby region or belt? What towns are within it?

316. What other knobby belt is there? What is said of the line of red knobs in this belt?

317. To what limestone is the color of the red knobs due?

318. What other interpolated bed is found in these shales?

319. Give a synopsis of the rocks about Knoxville?

320. What of the fossils in the Nashville group?

321. What of the minerals and ores of the Lower Silurian?

322. What is the aggregate thickness of the Upper Silurian formation?

323. How do its members outcrop in the different divisions of the State?

324. How many members have the Upper Silurian? What of the Upper Silurian on the eastern side of the Basin? Give the names of the divisions? General character of each?

325. Which is included in the Niagara period? Which in the Helderberg? What New York divisions are absent?

326. What follows next above the Nashville group? Of what does the Clinch sandstone consist in the northern part of the Valley? In what mountain is the sandstone conspicuous?

327. In what other mountains is the Clinch sandstone found?

328. What of the Clinch sandstone in the southern part of the Valley?

329. What is the Dyestone group? To what does it owe its importance and name?

330. What trio of formations make the Dyestone ridges?

331. What of the Clifton limestone? How is it divided in the Western Valley? What town is located upon it?

332. What of the glades?

333. Where is this limestone found in East Tennessee.

334. What of the fossils of the glades?

335. What of the Linden limestone? Where does the formation outcrop?

336. At what other points?

337. What of the fossils of the Upper Silurian?

338. What of the minerals of the Upper Silurian?

339. How do the Devonian and Upper Silurian compare in Tennessee?

340. What is the Black Shale?

341. What is said of the extent of the Shale?

342. What does the Black Shale contain?

343. What other outcrops are mentioned?

344. What are the fossils of the Black Shale?

345. What of the Devonian out of Tennessee? What of the Corniferous limestone?

346. What is said of the Carboniferous formation?

347. What are the four divisions of the Carboniferous formations? Give their characteristics.

348. What does the Barren Group include? What of its rocks? By what are the outlines of the Basin defined?

349. What other rocks of the formation?

350. With what formation is it associated in the Dyestone formation? What is the character of the group at Cumberland Gap?

351. What is said of the coral or St. Louis limestone?

352. What of the country lying at the western base of the Table-land? What towns upon it? What other large section based on the same rocks? What other towns are located on the St. Louis Limestone?

353. What is said in this paragraph?

354. What of the fossils in the St. Louis limestone?

355. How are the St. Louis limestone and the Barren Group considered in East Tennessee?

356. What is said of the Mountain limestone? Its thickness in the southern part of the State? Near the Kentucky line?

357. What of fossils in this limestone?

358. What of its occurrence in the Valley of East Tennessee? What of the fault at Montvale Springs?

359. What is said of the Coal Measures?

360. How many members in the Sewanee coal section? How many beds of coal?

361. How does the conglomerate, number 10, divide it?

362. What is said of the extent of the Lower Measures?

363. What is the thickness of the Upper Measures in the north-eastern part of the Table-land?

364. What is said of the formation of coal?

365. What towns upon the Coal Measures?

366. What of the minerals of the Carboniferous formation?

367. What of the Permian period?

CHAPTER XII.

Of what does this chapter treat?

368. Where do the Mesozoic and Cenozoic formations occur? What do we have in place of hard rocks?

369. What is said of the Mesozoic Time? What of animals and plants?

370. What is said of the Cenozoic Time? How many ages does it include?

371. What is said of the Gulf of Mexico? Where did the Old Shore line extend? What towns are situated upon it? What about the hard rocks? What is shown on map, page 116?

372. What formations are confined to West Tennessee? What of the Quarternary? In what Time is the cretaceous formation included? In what are the Quarternary and Tertiary?

373. What of the Triassic and Jurassic formations? What kinds of rock mostly prevail in them? What of the Trap Dikes which occur in these formations? Where else do the rocks of the Triassic and Jurassic age occur? What is meant by Triassic? What by Jurassic?

374. What is said of the Cretaceous formation? How many divisions has it? Name and describe them?

375. What is said of the Coffee Sand? What vegetable or mineral substance is found in the Coffee sand?

376. Where is the Coffee sand well exposed? In what other counties does it outcrop?

377. What is said of the Rotten limestone or Green Sand? From what does this sand take its name?

378. What kind of shells are found in this Rotten limestone?

379. In what states south of Tennessee does this Green sand also occur? In what counties of Tennessee is it found?

380. What is said of the Ripley group?

381. What often conceals the Ripley group? What towns rest on this formation?

382. How many divisions of the Tertiary formations are there in Tennessee?

383. To what do these two groups belong?

384. What is said of the Flatwoods Sand or Group? What is its thickness in Tennessee? How does it differ from the Ripley and Coffee group?

385. What may be seen along the course of the Memphis and Charleston Railroad? In what direction does this belt run? What towns are upon it?

386. What is said of the La Grange Sand? How wide is the belt, and in what direction does it extend? Describe this formation.

[illegible]

[illegible] reality

[illegible] workable [illegible]

occur in the Upper Measures? What do you mean by a workable seam? In what respect are the seams of the Upper Measures superior to those of the Lower?

403. What is said about the seams in the eastern edge of the coal-field? What is a flexure? What sometimes occurs in connection with these folds? What is said of the Upper Measures in the western counties of the coal-field?

404. What is said about the ravines in the coal-field? What of the main conglomerate in Anderson and Claiborne counties? What of the seams of coal in that portion of the coal-field?

405. How much coal will a seam one foot thick yield per square mile? On this basis how much coal is there in the State? How long will it last at the present rate of consumption?

406. How many leading varieties of coal? What does bituminous coal yield when heated? Is there any bitumen in bituminous coal? Why, then, is it so called?

407. From what is anthracite coal made? In what particular does it differ from the bituminous?

408. To what kind do Tennessee coals belong? How are bituminous coals classified? Describe coking coal. Non-coking. Cannel or Parrat coal. Why is the last called cannel coal?

409. What is the most valuable constituent in coal? What is the average composition of Tennessee coals? What substances injure coal?

410. What about the coal mines in Tennessee? Give the principal points at which coal is mined. How many men are employed in our coal mines?

411. What was the coal product of the State in 1854? What was it in 1875, and what was it worth? What is said about new mines?

412. What is Brown coal, or Lignite? Describe it.

413. How does Lignite burn? Where is it found? Describe the beds. What is Jet?

414. What is said of the bed at Raleigh? When should Lignite be mined?

415. Why should the student become familiar with this substance?

416. What is said about coal and Lignite? Of what use is Geology in this particular. Is it reasonable to expect to find coal outside of the coal formation?

CHAPTER XIV.

What is this chapter about?

417. How many iron belts are there in Tennessee? Name them. Where does this Eastern Iron Belt lie? The Dyestone? The Belt of the Cumberland Table-land? The Western Iron Belt?

418. Through what counties does the Eastern Iron Belt pass? How many classes of ore in this belt? Name them? How are they recognized? What powder does limonite give? Hematite? Magnetite?

419. Which is the most abundant? What is the difference in composition between limonite and iron rust? What per cent. of iron does it yield? Give the names of the various forms in which limonite occurs. What does limonite mean?

420. How does limonite occur in the Eastern Belt? With what mineral is it associated in Greene county? What sort of iron is made from a mixture of iron ores with the oxide of manganese? What is this iron used for?

421. What does hematite mean? How does hematite differ from limonite? Can you make hematite from limonite? How. When pure, how much iron does hematite yield? What is said about Dyestone?

422. In what localities in the Eastern Belt does the hematite occur?

423. What is said of magnetite? From what does this ore take its name? Where does it occur, and how? Where, in Tennessee, is it found in workable quantities? What is a loadstone? What of this ore in North Carolina?

424. Describe the Dyestone Belt.

425. To what variety of iron ore does the Dyestone belong? What does it yield? Why called Dyestone? Why Fossil ore and Oolytic ore? What is its color? Is it hard or soft?

426. Is it found in banks or nests, or in strata? What is the thickness of the strata? What is said of the stratum skirting the Cumberland Table-land?

427. Name the localities where good deposits are found? With what rocks is the Dyestone associated? In what formations does is occur?

428. Name the counties which contain this ore in workable quantities.

429. What advantages does the Dyestone Belt afford for the manufacture of iron?

430. What is said of the ores of the Cumberland Table-land?

431. Describe the Western Iron Belt. What counties does it include?

432. What variety of ore is found in this belt mainly? Where and how does it occur? Give the typical features of a bank in this belt?

433. What is said of pot ore? What is said of the hills and ridges containing ore? Is any found in the valleys and river basins?

434. Give the localities where the best deposits of ore occur in this belt? What may these localities be regarded as?

435. What is said of the ore near Clifton, in Wayne county? What counties on the eastern side of the Highland Rim contain ore?

436. What fuel is used in the eastern and western Iron Belts? How

many bushels of charcoal does it take to make a ton of iron. What fuel is used in the Dyestone Belt? What is coke? How much coke does it take to make a ton of iron? When was stone coal first used for making iron in Tennessee?

437. What has iron been called? Is there any other metal more used in domestic puporses? Give some of its uses.

438. How many classes of iron products are there? Name them.

439. What is cast or pig iron? Describe it. Can it be hammered? What is the average annual production in the State, and its value? How many furnaces? Where are they?

440. Describe in full the process of smelting ore? What office does the lime perform? The coal? What is slag? Why is the limestone called a flux?

441. How is wrought or soft iron made? What do you understand by puddling? What is the object of puddling? With the loss of carbon what does the iron lose? How is it otherwise changed? What is done with it after it is taken from the furnace? What about its specific gravity?

442. Is there any other process by which wrought iron is made? Describe it. How many of these forges in Johnson, Carter, and Campbell counties? What is their average production? At what other points is malleable iron made?

443. What effect does phosphorous have upon iron? Sulphur?

444. What is steel? Its specific gravity? Give the points of difference between steel and wrought and pig iron? At what place in the State is it manufactured?

445. What advantages does Tennessee offer for the manufacture of iron?

CHAPTER XV.

446. What is embraced under the head of other useful minerals?

447. What rank does copper take among the useful minerals of the State? In what portion of the State does the copper-bearing district lie? How high is it above the sea? Describe its general appearance? In what formation is the copper found?

448. How many copper veins have been found in the State? What lies above them? What does gossan mean?

449. Describe Black Copper ore or Senonite. Cuprite. Malachite. Azurite. Copper pyrite. How is copper pyrite distinguised from gold or iron pyrite? How does native copper occur? What is meant by dendritic? Describe Blue Vitriol.

450. Are there any other ores of copper about Ducktown?

451. How many persons find employment in the copper region? How much copper is made? Its value? Number of furnaces?

452. How many ores of zinc in Tennessee? What are they? Describe Sphalorite. Smithsonite. Calamine. With what other ore is the zinc associated? How do the zinc ores occur?

453. In what localities are the most extensive deposits found? How do the veins occur in Union county?

454. What about the zinc ores at Mossy Creek, in Jefferson county?

455. What ores of lead are found in the State? Describe galena. Cerussite.

456. Is galena found associated with any other mineral? How does it occur in Union county? Washington? McMinn? What about the vein in Bradley county? At what other places has galena been found?

457. What about the gold of Tennessee?

458. What is iron pyrite? Describe it. Where is it found?

459. Is it of any practical value in Tennessee? What about its use in England?

460. How is iron pyrite distinguished from gold?

461. Describe the oxide of manganese. How can you tell it from the iron ores? For what is it used?

462. What is said of barite or barytes? What is the annual production of the State? Where does it occur?

463. What is copperas, and where is it found?

464. Where was it manufactured during the late war? From what? What is copperas used for?

465. What is said of alum?

466. What is said of petroleum?

467. What can be obtained from Black Shale by distillation? Why is Black Shale often mistaken for coal?

468 What is said about salt?

469 What about nitre? What is nitre used for?

470. What is said about Epsom salts?

471. Tell what is said about gypsum? What is selenite?

472. What kinds of mineral waters abound in Tennessee? Where? What about sulphur wells? What is the most fruitful source of sulphur waters?

473. What is said about the mineral springs generally?

CHAPTER XVI.

What is this chapter about?

474. What uses are made of rocks and clays?

475. What is said of limestones? Their colors? Their occurrence?

476. Of what is the State capitol built? Describe this limestone?

477. What about lime?

478. What is marble?

479. What is said of the marbles of Tennessee? Give the varieties. What is said of black marble?

480. What counties have furnised the largest supplies of gray and variegated marbles? How does the marble lie in Hawkins and Knox?

481. For what is the red variegated prized? How does it appear when polished?

482. In what public buildings has this marble been used?

483. What about the marbles at other places in the State? What about the magnesian marble?

484. Describe the conglomerate and breccia marbles. In what counties do they occur? When polished, how do they appear? How many quarries of marble are worked in the State?

485. What is said of gneiss or stratified granite? What is syenyte? Unakyte?

486. What is said of sandstones? Will any of them make whetstones?

487. What are flagstones, and where do they abound? What of the iron limestones?

488. What is Orange Sandstone, and where is it found? To what formation does it belong?

489. What is said of the Saccharoidal sandstone?

490. What is meant by hydraulic cement? From what is it made? Of what do the impurities consist? In what counties do cement rocks abound? Where is the cement manufactured? From what is cement made in Knox county?

491. What is said of roofing slate?

492. What of millstone grit?

493. What of the masses of chert of the Knox Dolomyte formation? What counties abound in these cherty masses? What is found below the Black Shale formation at certain points? What counties afford the largest quantities of this material? What other stone has been used for millstones?

494. What is said of lithographic stone?

495. What of clay for fire brick?

496. What of potter's clay, and where found? What of kaolin?

497. What constituents of the Green Sand formation supply a natural fertilizer? What does an analysis of the Green Sand disclose?

498. What is said of glass-making material?

CHAPTER XVII.

What is this chapter about?

499. What is the soil, and what is the subsoil?

500. Of what two parts does soil consist? What is the Organic?

Inorganic? In what do the soluble and insoluble parts consist? What are the principal insoluble ingredients?

501. From what are soils derived? Are the alluvial soils dependent upon the underlying rocks? Why not?

502. Tell how hard rocks are converted into soils?

503. Into how many classes are the soils of the State divided? Give the first, with the leading characteristics. The second. Third, etc.

504. Where are the granitic soils, and what is said of them?

505. How many varieties of sandstone soils are there? Name them.

506. What of the Chilhowee Sandstone soil? To what part of the State is it confined?

507. What is said of the Knox Sandstone soil, and where is it found?

508. What of the Clinch Mountain Sandstone soil? What are its characteristics?

509. What is mentioned as a singular fact in relation to the Clinch and some other mountains in East Tennessee?

510. What is said of the Dyestone soil, and where does it occur?

511. What area does the soil of Cumberland Table-land occupy? What are its distinguishing characteristics?

512. What are its defects? What is said about the swampy places on the Cumberland Table-land?

513. What are the characteristics of the best soil of this division? In what does the agricultural value of the lands of the table-land consist? What crops may be grown?

514. What is said of the siliceous or flinty soil, and where does it prevail? How may you tell the good lands of the barrens?

515. What are these siliceous soils good for?

516. What is said of sandy soils, and where do they occur?

517. Is a sandy soil always poor? What gives it vitality? What other important consideration is mentioned?

518. Where is the calcareo-siliceous soil? Describe it. To what does this owe in part its good qualities? What is said of the crops and timber of this soil?

519. What is said of the calcareous soils of the State? Where are they found, and what do they produce? What proportion of the State do they cover?

520. What about the Green Sand soil, and to what does it owe its fertility? Where is it found?

521. What is said under the head of Shaly Soil?

522. What is said of alluvial soil, and where is it found? How do the alluvial soils differ, and what is the cause of this difference?

523. What about the elevated terraces, and their value as farming lands?

524. Do the various soils overlap or run into one another?

525. Upon what does the productiveness of soils depend?

526. What is the effect of standing water upon field crops? What if a soil is too porous? What is the best condition of a soil for the purposes of production?

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